PRODUCT ENGINEERING

JULY, 1952

UNIVERSITY OF MICHIGAN
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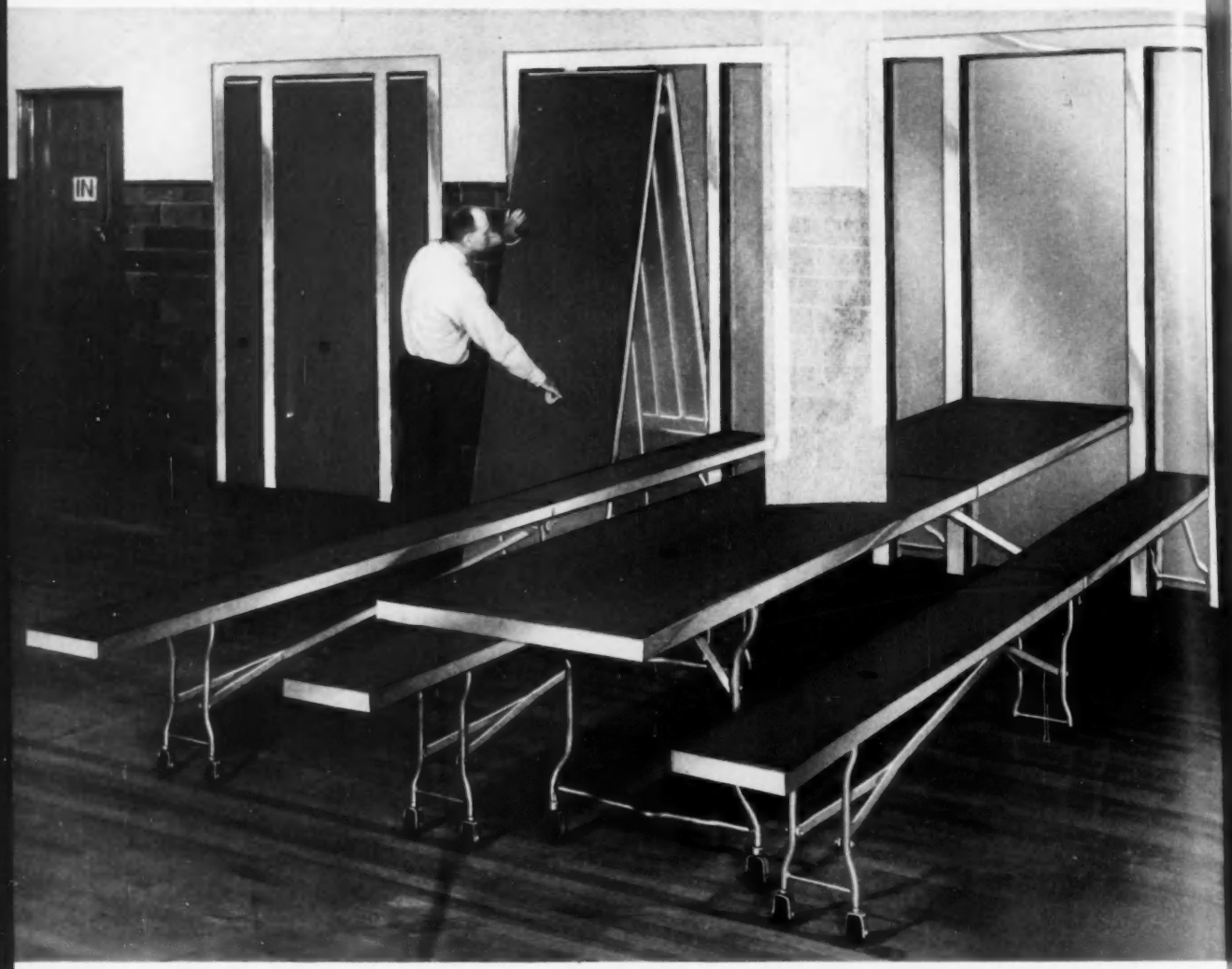
PERFORMANCE TESTING OF HYDRAULIC DRIVE

SHARON STEEL



Basketball in the dining roo

● The multiple use of space is a modern trend in architecture made possible largely because of many new steel products. School gymnasiums double as lunch rooms, large church areas can be made to serve both as recreational centers and supper rooms, Y.M.C.A. and other club and lodge buildings can make better use of the space available because of *In-Wall* steel tables and benches that quickly, silently and easily fold in and out of the wall as the occasion demands.

Because these tables are constructed of strip steels and welded steel tubing they are light, yet rigid, easily maintained and fireproof. The lightness enables quick set-ups. A single man can roll out 10 tables in eight minutes. The rigidity prevents twisting and warping. The tables fit snugly, but will not bind in their casements. The smooth steel surface makes sanitation a simple matter.

Too, the use of strip steel means the fabrication and material cost of these tables can be held to a minimum.

If you use steel — stainl special alloy, coated or plain bon—it is good business to h Sharon high on your supplier for Sharon is one of the wo largest producers of quality steels.

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For information on Titanium contact Mallory-Sharon Titanium Corp., Niles, Ohio

VOLUME 23 — PRODUCT ENGINEERING — NUMBER 7

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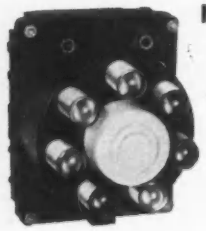
Let Mallory Help You Solve Your Switch Design Problems

Mallory offers you these three outstanding advantages . . . in the design and production of switches. Three recent examples, in the appliance field, are illustrated below.

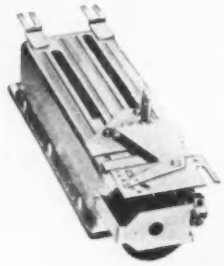
1 Production facilities geared to turn out quality switches in quantity . . . at reasonable cost.

2 Engineering and design service backed by years of experience in producing a diversified range of switches noted for long-lasting, trouble-free service.

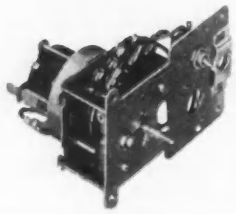
3 A ready-to-use supply of all-purpose tools and basic switch designs which often make it possible to produce special switches *without* special tool and design expense.



New Circular Type Push Button Range Switch. This brand new Mallory switch features a unique contact design using specially selected alloys to insure long, trouble-free service. Designed for use on back-splash or front stove panel, this Mallory switch is easy to mount and requires very little space. The switches are made with a minimum of critical materials, thus assuring availability. Consumer features include special push button coloring for easier heat selection . . . good spacing for easy cleaning.



Slide-type Timer Switch. Designed for back-splash mounting and developed in conjunction with the customer's engineers, this Mallory-made switch permits the timed sequence to be shown in a straight line rather than in dial form. Contact design prevents partial contact which might result in a burned out motor. Plug-in terminals are an integral part of the switch circuit to provide low resistance and improve electrical efficiency.



Rotary Timer Switch. The outstanding characteristic of this Mallory switch, also developed in conjunction with customer's engineers, is that it can be adapted to include a wide variety of features with a minimum of special tooling. The basic Mallory design lends itself to the incorporation of the customer's particular requirements.

In addition to appliance switches like those shown here, Mallory is prepared to design and produce switches for every conceivable circuit combination encountered in radio and television, test equipment, industrial electric and electronic equipment, and medical electronic equipment. Contact Mallory today for help with all your switch problems.

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For information on titanium developments contact Mallory-Sharon Titanium Corp., Niles, Ohio.

Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

TOUGHNESS AND IMPACT RESISTANCE at temperatures down to -60 F are the advantages of Kralastic J, a styrene copolymer developed by the Naugatuck Chemical Div. of U.S. Rubber Co. Initial uses are expected to be in military equipment operated in arctic regions.

A "WELD-THROUGH" SEALER originally used in cars is available from 3-M's Adhesives and Coatings Div., Detroit 2, Mich. Applied to surfaces before spotwelding, the heavy paste is said to resist heat to 475 F and the pressure of welding without splattering or burning. At same time, material yields to pressure of electrodes and permanently excludes moisture from joint.

A DISK of cellular silicone rubber is the heart of an automatic vent valve used in water heating systems. Uncompressed, the disk forms a "cellular" orifice that passes air. Water causes companion hydroscopic disks to swell, thus compressing the rubber disk and stopping flow. When hydroscopic disks are dry, air again flows through the cellular rubber, which is made by Sponge Rubber Prod. Co., Shelton, Conn.

AMORPHOUS SELENIUM has desirable optical qualities in the infra-red light range. Physicists at England's University of Reading found that selenium lenses can have short focal lengths, yet at the same time, large radii of curvature. A high refractive index accounts for these desirable characteristics.

A NEW SERVICE, which will package colors for all plastic resins in specified amounts, has been set up by Ferro Corp. of Bedford, Ohio. Each color is accurately weighed to insure the exact shade desired and sealed in plastic bags. Standard transparent colors are green, blue, amber and red; translucent tints include white, green, pink, yellow, blue, brown, black, red and maroon.

BLENDING of polyisobutylene and polyethylene results in a material softer than polyethylene, but of equal temperature stability. Various formulations based on a DuPont patent are in production at Westchester Plastics, Inc. in Mamaroneck, N.Y.

HUMIDITY RESISTING ORGANIC COATING for polystyrene has been developed by Standard-Toch Chemicals, Inc., Staten Island 3, N.Y. Styrophane can be applied by spray to injection molded polystyrene parts and is said to have excellent wetting characteristics, good flow and no tendency to craze. Tests indicate it resists chipping, cracking, abrasion, fats and grease.

METALLIC MATERIALS

STEEL-ALLOY CASTINGS of low nickel content may ease the nickel shortage for applications within the intermediate temperature range from 900 to 1,400 F. Research at Battelle Memorial Institute, Columbus, Ohio, shows that users may, in some applications, be able to substitute a 21 percent chromium, 9 percent nickel alloy for materials containing 30 to 100 percent more nickel.

FIVE NEW TITANIUM ALLOYS were patented recently (U.S. Nos. 2,596,485-89) and assigned to Rem-Cru Titanium, Inc. Four of the patents concern the addition of specific metals—antimony, bismuth, boron and indium, – to a titanium-aluminum alloy. Resulting properties combine high strength with good ductility. Fifth patent covers a titanium alloy containing aluminum, chromium and molybdenum.

NEW CATHODE ALLOY, the first of a series trademarked Cathaloy, contains 0.1 percent aluminum as the main reducing agent for the cathode coating. Developed primarily for use in all types of vacuum tubes, these alloys have longer life, lower interface impedance, higher emission and greater mechanical strength than standard specially-melted cathode compositions.

(continued on page 7)

THOUSANDS OF SMALL CONIFLEX® GEARS ARE CUT DAILY

With the new Gleason No. 2 Straight Bevel Generator thousands of small size straight bevels with localized tooth bearing are cut daily. The latest development in the cutting of small Coniflex® gears uses interlocking-type cutters which, operating in a single tooth space, complete each space from the solid metal in one operation.

It is ideally suited to the manufacture of Coniflex® gears to be used in such applications as typewriters, business machines, instruments, ordnance equipment, hand tools and many others.

When high productivity is the object, a fast, reliable automatic loader is available for this machine.

Write for leaflet describing how this modern, high speed, completely automatic machine can produce small Coniflex® gears for you.

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FOR SEALING VEHICLES such as tanks and other military equipment prior to storage or shipment, the Ordnance Dept. is using aluminum foil embedded in an adhesive mastic. Latter is spread around openings to be sealed and the foil placed over the openings with edges anchored in the tacky resin. No moisture was found in a unit sealed for eight months.

BY ADDING TWO OR FOUR percent rare earth metals to cast magnesium-zirconium alloys,

Dow Chemical has come up with alloys that exhibit at 300 F and above as much as five times the creep strength of standard Mg-Al-Zr type alloys. Main applications are expected to be aircraft engine components that require outstanding elevated temperature properties.

STEEL BOLTS in aluminum structures receive complete protection from an 80-20 tin-zinc alloy plating. In tests conducted at the Fulmer Research Institute, Stoke Poges, Buckinghamshire, England, tin-zinc covered specimens outlasted samples that had been zinc plated, block oxide finished, cadmium plated and phosphate coated.

PROCESSES

A 15,000-TON FORGING PRESS, originally built in Germany during the war, has been shipped to this country and installed by Alcoa in its Cleveland plant. Structure is 54 ft high and has a die press table measuring 21 by 7 1/2 ft. Leased from the U.S. Army Air Force, the giant will be used to produce large magnesium forgings.

A PRACTICAL ANSWER to the problem of melting, purifying, alloying and agitating both inert

and reactive metals is electromagnetic levitation, wherein no crucible is needed. Metals such as titanium and molybdenum become molten and remain suspended in opposing electromagnetic fields. Mass is held together by surface tension, according to reports from Westinghouse.

TO PREVENT ZIRCONIUM from oxidizing at working temperatures (1,500 to 1,700 F), ingots are sealed in a sheath of iron and then worked to size. Sheath is subsequently dissolved in acid. Tests at the Bureau of Mines indicate that, with such sheath-working techniques, the metal loss can be held to 5 percent and the recirculating scrap to approximately 25 percent.

SUBSTANTIAL ECONOMIES can be effected by extracting metals from low grade ores by chemical rather than by smelting methods. The process involves the leaching of metal from the ore in an autoclave under high temperatures and pressures. According to Chemical Construction Corp (American Cyanamid affiliate), recovery is about 100 percent. Method is applicable to the recovery of copper, nickel, cobalt and other scarce metals. The first commercial plant will be near Salt Lake City for extraction of cobalt.

HOLLOW METALLIC O-RINGS filled with inert gas at 600 psi provide a static seal against pressures to 20,000 psi and withstand temperatures limited only by the physicals of the metals — stainless steel and mild steel cadmium or nickel plated. United Aircraft Prod. Inc. of Dayton, Ohio has small quantities in sizes ranging from 11/16 to 40 in. OD in increments of 1/16 inch.

COMPONENTS

SPEED REDUCERS containing heavy-duty herringbone gear sets made of ductile iron performed well during tests conducted by

Lufkin Foundry & Machine Co. of Lufkin, Texas. Data indicate that properly controlled nodular gears can carry the full rating currently used by AGMA for rating steel gears. Ratio-hardness curves developed limit loading of ductile iron gears at 180 Brinell to about 10 percent below that for steel.

MINIATURE ELECTRICAL COMPONENTS stand to benefit from fine-diameter extruded plastic tubing developed by the Irvington (N.J.) Varnish and Insulator Co. Made of polyvinyl chloride, tubing has ID of 0.012 in. and a 0.012-in. wall.

SIMPLE DIALING DEVICE changes in a few seconds the rotation or voltage of a new line of capacitor motors perfected by The Brown-Brockmeyer Co., Dayton, Ohio. Motors so equipped have two leads, making relocation easy.

NEWEST BEARING for use on high-speed shafts combines the desirable features of needle, journal and cylindrical roller bearings, according to Roller Bearing Co. of America, Trenton, N.J. This so-called pitch line bearing has same dimensional advantages as needle bearings, flexibility of mounting and easy maintenance of journal type and roller alignment formerly found only in precision bearings.

(continued on page 9)

Another new development using

B. F. Goodrich Chemical *raw materials*

Hycar helps diesels make the right connections

Control jumper manufactured by Pyle-National Co., Chicago, Ill. B. F. Goodrich Chemical Company supplies the Hycar rubber only.

THIS "juice" connector for diesel locomotive units lives a rough life—but a good and long one, thanks to Hycar rubber!

The connector, or electrical control jumper, consists of a 250-volt multi-conductor cable and two plug heads molded in Hycar. These are vulcanized together to form a one-piece unit—may have as many as 27 circuits. It carries vital power for the train . . . rides the rails under all kinds of tough conditions.

It must withstand oils, chemicals, and extreme temperature changes. It must resist the damaging effects of coal dust, salt water spray and greases. When disconnected and carried from one diesel to another, the heavy jumper is sometimes dragged along the road bed—an extra beating that it takes in stride.

Taking all that punishment—and more—is Hycar's job. For Hycar rubber can be made to resist heat and cold . . . water, weather and wear . . . gas, oil, many chemicals and more damaging conditions.

Designers and molders find Hycar rubber compounds help improve or develop many products. They may be just what you need. We'll gladly help you, with technical bulletins and advice. Just write Department HP-4, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. In Canada: Kitchener, Ontario. Cable address: Goodchemco.

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Hycar
American Rubber

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers • HARMON organic colors

MINIATURE CONNECTORS called Varicons have been developed by Elco Corp., 190 W. Glenwood Ave., Philadelphia 40. Any required polarity or number of contacts can be obtained through combinations of four basic components. The rated potential is 1,330 volts.

SELF-LOCKING screws and bolts have a small resilient nylon plug inserted radially near the bottom of the threads. Lateral thrust wedges threads together wherever fastener is stopped. The Nylok Corp., 475 5th Ave., New York City, claims no safety wire or lock washers are needed.

STEPPING POSITIONER DRIVE weighing 0.8 lb, and rotatable 360 deg left or right is suitable for driving various low-torque mechanisms such as indicators, potentiometers, selsyns and some synchros. Device is solenoid-operated, normally rotating in two-deg increments, say the makers, G. M. Giannini Co., Pasadena, Calif.

TO ACHIEVE higher operating temperatures, transistors may some day be made of silicon instead of germanium, Dr. J. P. Jordan of General Electric predicted. Existing junction-type germanium transistors can handle power of 100 milliwatts, and if cooling is used, up to two watts. Increased transistor power capacity should come from a larger transistor working area, rather than from added cooling.

TESTING

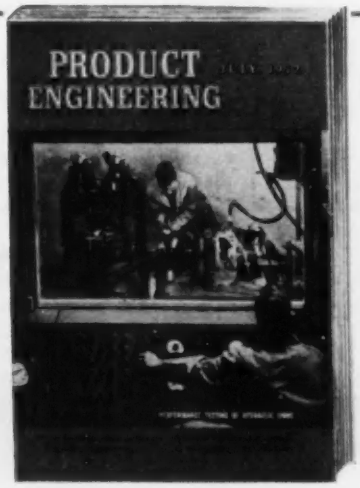
TRACING CLOTH for engineering drafting work has a "super-velvet" pencil matte surface that provides clearer translucency, better drawing surface and greater durability than many existing products. Tradenamed, Brutex, cloth is made by Charles Bruming Co. of Teterboro, N. J.

A SINGLE TRANSMISSION takes the place of three or four generally needed to send full color pictures via wire or radio. Patent 2,598,504, assigned to Times Facsimile Corp., New York City, covers this development that promises to reduce distortion now caused by differences in the conditions of successive transmissions.

POCKET SLIDE RULE incorporates a two-color pencil, eraser, lead chamber and detachable straight-edge ruler. Removable print magnifier and depth gage are part of the vest-pocket clip. Made by Device Development Co., New York City 14, pencil shaped assembly is 6 1/2 in. long and weighs less than an ounce.

A TENFOLD INCREASE in sensitivity is claimed for a projection balance made by Voland and Sons of New Rochelle, N.Y. Unit is for rapid, accurate weighing of quantities up to about 7 oz. Weighings to one-tenth of a milligram can be made within seconds by a straight projection, or to one-hundredth of a milligram by sensitivity shift and an additional set of ten weights.

A NEW SOURCE of intense atomic energy may come out of experiments being carried on at MIT. The source is positronium, a short-lived material made of the simplest atom yet discovered. It is formed by making a positron connect with a negatively-charged electron. Thus in structure, it is somewhat similar to hydrogen which has a negatively charged electron spinning around its positively charged nucleus.

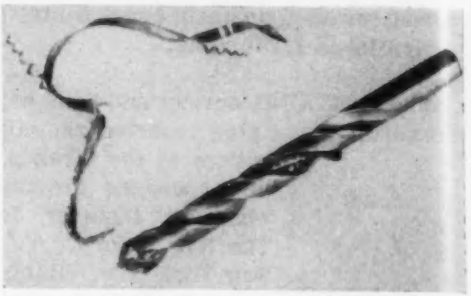


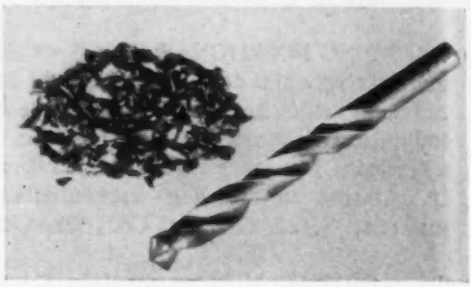
THIS MONTH'S COVER

Featured on the cover this month is a test cell in the hydraulic production test laboratory of the Hydraulic Division, Sundstrand Machine Tool Company. Here Constant Speed Alternator Drives are tested singly and with two or more operating together under conditions simulating actual operating conditions. After tests for efficiency, load capacity, acceleration, and governing characteristics, these transmissions are shipped for installation on Air Force and Navy aircraft. The drive, shown under test, is a mechanical hydraulic differential-type transmission. It is rated at 50 hp continuous output with overloads to 100 hp and for input speeds from 2,500 to 9,000 rpm. This unit converts the variable speed obtainable from an aircraft engine to constant output speed suitable for driving an alternating current generator.

Tests Prove the Fabricating Economies of Free-Cut Invar "36" Developed by *Carpenter*

It wasn't too long ago when men fumed and sweated over machining of invar. In fact, the value of this alloy's low coefficient of expansion was greatly handicapped by its lack of machinability. Then Carpenter laboratories introduced a *free-machining* invar known as Free-Cut Invar "36". The tests listed here show how machining problems have been solved with Free-Cut Invar . . . and demonstrate why industry has been able to open whole new fields for invar's use where formerly it was avoided because of difficulties in machining. Here is another example of Carpenter's pioneering role in the development of new and finer steels to make possible the "impossible" of yesterday. THE CARPENTER STEEL COMPANY, 117 W. Bern St., Reading, Pa.





In this test, a 2 3/16" thick block of each grade of invar was used. The drill shown in the top photo cut through 1 1/16" of regular invar and was badly burned. The drill in the bottom photo cut through the entire block of Carpenter Free-Cut Invar "36" without failing. The chips to the left of each drill are those produced in the respective tests.

RELATIVE MACHINABILITY OF *Carpenter* FREE-CUT INVAR "36"

OPERATION	REGULAR INVAR (non-free-machining)		Carpenter FREE-CUT INVAR "36"	
	SPEED	REMARKS	SPEED	REMARKS
ROUGHING (Bar 1" round) Cut: 3/32" Feed: .0055"	28.80 sur ft/min	Machining satisfactory.		
	49.22 sur ft/min	Tool failed after cutting about 1" along bar.		
	82.47 sur ft/min	Tool failed after only a few revolutions.	82.47 sur ft/min	Machining satisfactory. No effect on tool.
			137.45 sur ft/min	Top speed for the lathe used. No indication of failure. At this speed feed was increased from .0055" to .0125" with results still satisfactory.
FINISHING Cut: .050" Feed: .0055"	23.40 sur ft/min	Indications were that this speed provided the best possible finish.	111.67 sur ft/min	This speed gave a very good finish. With feed increased to .0125" the finish was still good.
	NOTE: This test made to determine highest speed possible for satisfactory finish.			
DRILLING 7/16" round high-speed drills. Test block 2 3/16" thick. Feed: .004" per revolution.	665 rpm	Drill failed completely when hole was only 1 1/16" deep.	665 rpm	Drill went through entire 2 3/16" test block with ease. After test, drill still in good condition.
THREADING Single point tool. Ten threads per in. Two roughing cuts @ .04". Two finish cuts @ .004".	60 rpm	Two rough cuts resulted in "torn" threads. Two finish cuts failed to provide satisfactory threads.	188 rpm	Same number of rough and finish cuts made. Threads greatly superior to those on regular invar sample.
	NOTE: This test made to determine highest speed for best possible threads.			

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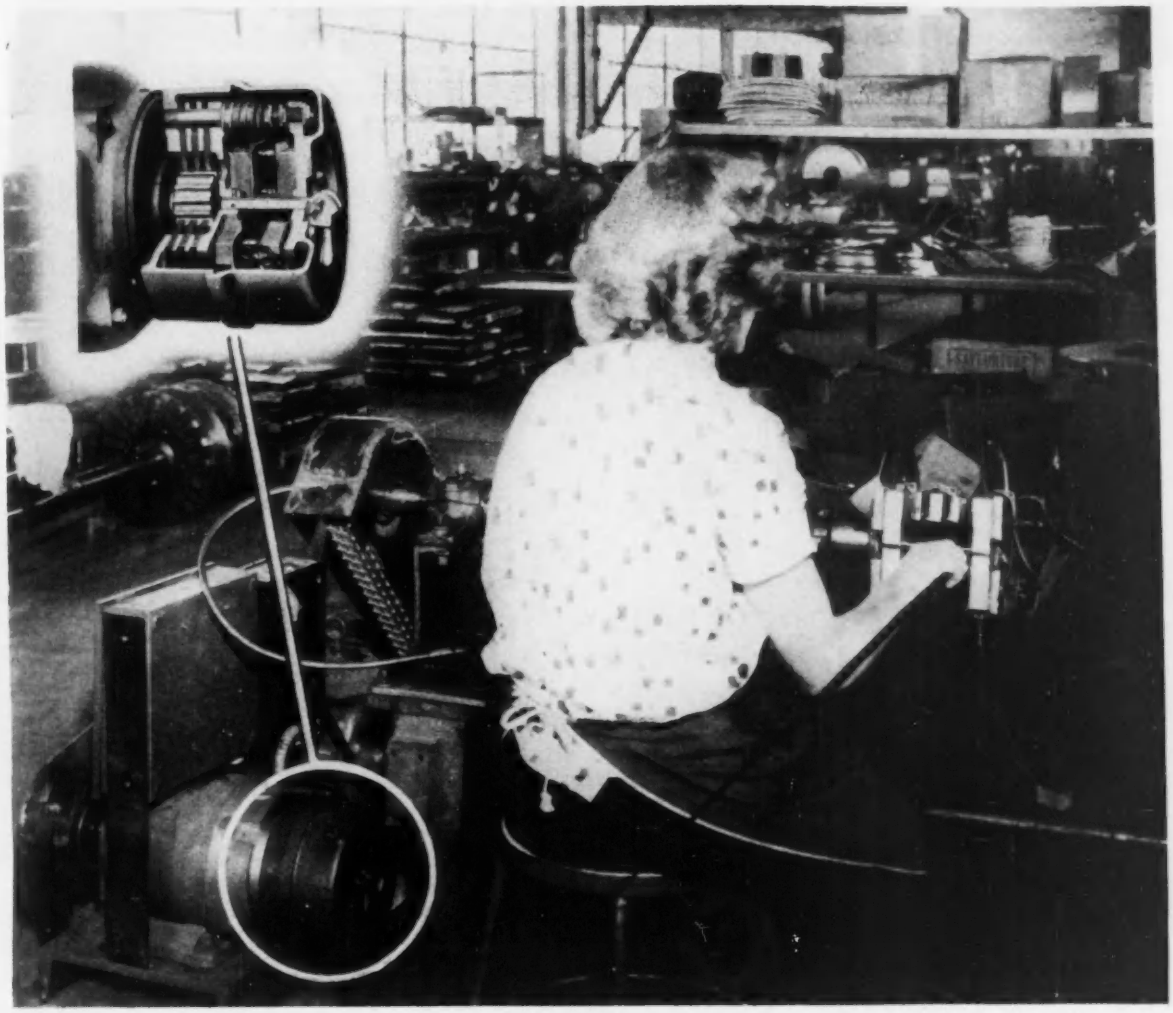

Magnetic brake mounted on 3 hp drive motor of coil winding machine averages 10 stops per minute during year-round operation.

Selecting Motor-Mounted Magnetic Brakes

J. Aude
Dings Brakes, Inc.

WHENEVER MAGNETIC BRAKES ARE USED for reducing the stopping time of electric motors in cyclic operations such as those encountered in production-line machinery and lifting cranes, the restraining force acts through the angular distance traveled by the brake during the stopping period and brings the load to rest. Too small a brake not only fails to shorten the stopping time sufficiently, but also imposes a limit on the number of stops per minute that can be made without overheating the brake; too large a brake may shorten the stopping time to the extent of damaging the load. The ideal brake selection is one that produces a reasonable stopping time and is worked near, but not in excess of, its rated thermal capacity. If a larger brake torque must be selected to obtain sufficient thermal capacity, the torque can generally be adjusted downward to suit the shock that the load will stand during stopping. This adjustment does not change the thermal load the brake can absorb, except on overhauling loads.

Selection by Motor Considerations

In the absence of specific data needed to select a brake on the basis of thermal capacity, as explained be-

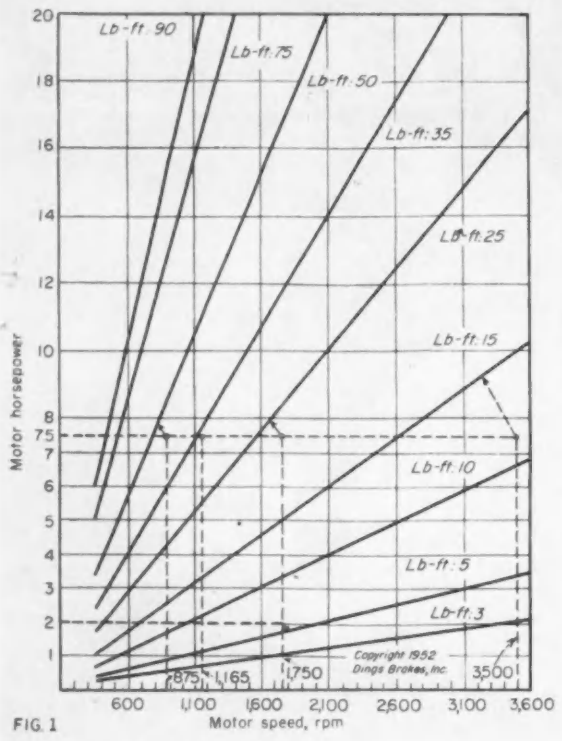

FIG. 1

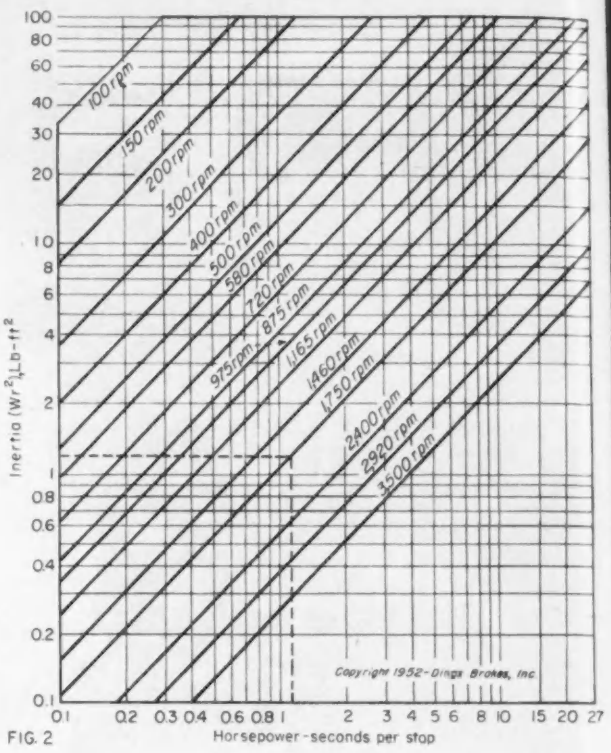

FIG. 2

low, brake torque should be made equal to the full-load torque of the motor to which it is attached. Referring to Fig. 1, a 7.5-hp motor running at 1,165 rpm has a full-load torque of about 34 lb-ft. The nearest standard size is the 35 lb-ft brake, which is therefore chosen. When the hp-speed intersection on Fig. 1 lies just above a brake line, such as two horsepower at 1,750 rpm, the smaller torque brake may be used, in this case a 5 lb-ft brake.

The stopping time of a brake selected in this manner is referred to the time taken by the motor to start the load, and figured from the average accelerating torque of the motor. This torque is the time average of the instantaneous difference between the torque developed at the motor shaft and the resistive torque of the load, for the starting period only. Thus, if a motor develops an average torque of 10 lb-ft over and above the frictional torque of the load in a one-second starting period, then a constant application of 10 lb-ft braking torque during one second will bring the load to rest (neglecting the helping effect of friction).

For polyphase squirrel-cage induction motors starting without useful output load, the average accelerating torque is generally in the range of 100 to 200 percent of motor full load torque. Therefore, with these motors, the stopping time of a brake selected on the basis of full-load torque of the motor is 100 to 200 percent of the time taken by the motor to start the load. This is usually satisfactory for general-purpose work. When started under work load, these motors take proportionately longer to start, and, if braked while under load, stop in proportionately shorter time.

Ordinarily, a motor with high average accelerating torque is intended for driving machines that are started and stopped under heavy useful work load, such as positive displacement compressors. The resisting torque presented by the load is then sufficient to stop the motor and load quickly without a brake. It is therefore customary to think of brake applications on the basis of full-load motor torque as stopping the load in the same time as taken by the motor to start the load.

Brake Heating vs Motor Heating

Considering the system of selection used as the basis for Fig. 1, a 15 lb-ft brake could be applied to a motor as large as 10 hp operating at 3,500 rpm. The continuous thermal absorption rating of this brake is in the neighborhood of $\frac{1}{6}$ hp. Although expressed as 125 watts by some manufacturers and as 10 hp-sec per minute by others, these three quantities are equivalent.

The $\frac{1}{6}$ hp brake can thus be applied to a 10 hp motor, which is built to dissipate 1.36 hp of loss continuously while at 88 percent full load efficiency. The ratio of continuous heat dissipation capacities is therefore: 1.36 divided by $\frac{1}{6}$ or approximately 8 to 1. This ratio is borne out by the physical size of the two units, the motor having several times more cooling surface than the brake. It follows, therefore, that unless the motor heat per start is about eight times the brake heat per stop (11 percent average starting efficiency), the brake will not be matched to the motor in thermal capacity. And for the worst operating conditions, that of rapid start-stop, there is little or no run[illegible] time at full load.

Fortunately for the brake, the efficiency of the motor is low during the starting period. Thus the standard motor is not likely to be started oftener than the brake is able to stop a given load, particularly if the drive is started and stopped under useful output load. Standard motors, however, vary sufficiently in their capacity to start under load without overheating. It is therefore advisable to refer to the motor manufacturer for a check on motor heating for the exact duty cycle encountered when: (1) The number of

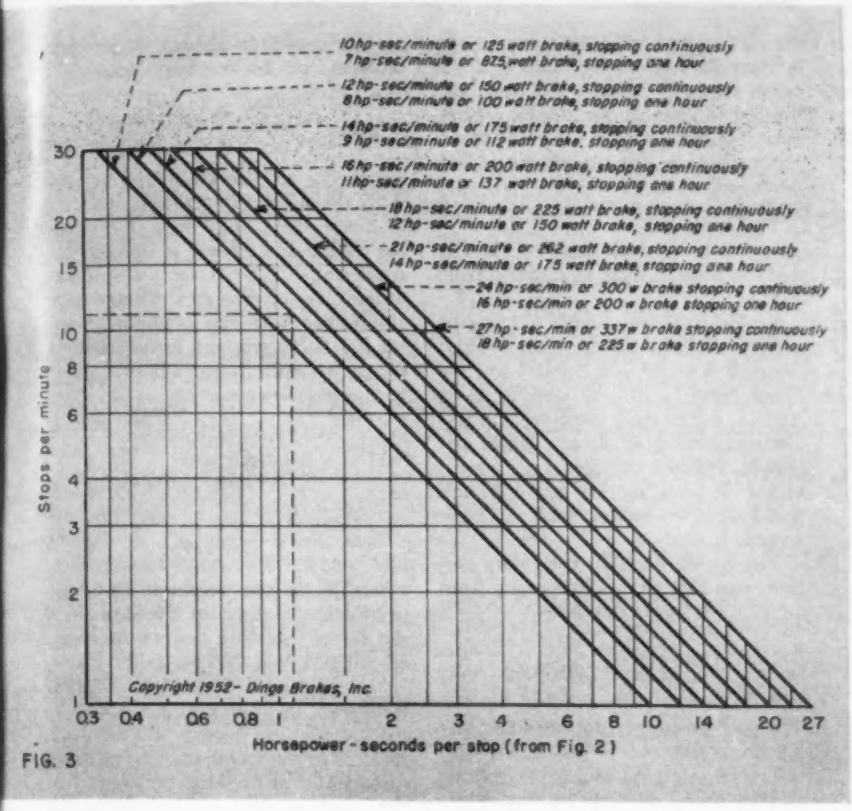
10 hp-sec/minute or 125 watt brake, stopping continuously
7 hp-sec/minute or 875 watt brake, stopping one hour
12 hp-sec/minute or 150 watt brake, stopping continuously
8 hp-sec/minute or 100 watt brake, stopping one hour
14 hp-sec/minute or 175 watt brake, stopping continuously
9 hp-sec/minute or 112 watt brake, stopping one hour
16 hp-sec/minute or 200 watt brake, stopping continuously
11 hp-sec/minute or 137 watt brake, stopping one hour
18 hp-sec/minute or 225 watt brake, stopping continuously
12 hp-sec/minute or 150 watt brake, stopping one hour
21 hp-sec/minute or 262 watt brake, stopping continuously
14 hp-sec/minute or 175 watt brake, stopping one hour
24 hp-sec/min or 300 w brake stopping continuously
16 hp-sec/min or 200 w brake stopping one hour
27 hp-sec/min or 337 w brake stopping continuously
18 hp-sec/min or 225 w brake stopping one hour
Stops per minute
30
20
15
10
8
6
4
3
2
1
Copyright 1952 - Dings Brakes, Inc.
0.3 0.4 0.6 0.8 1 2 3 4 6 8 10 14 20 27
Horsepower - seconds per stop (from Fig. 2)

FIG. 3

Fig. 1—Selection of brake by motor horsepower and speed. Sample plots for 2.0 and 7.5 hp motor show proper selections for standard speeds.

Fig. 2—First two system constants—inertia (Wr^2) of parts (1.2) and speed from which stop is made (1,750 rpm)—determine hp-sec per stop (1.1) in the thermal-capacity method of brake selection.

Fig. 3—Product of hp-sec per stop (from Fig. 2) and stops per minute (third constant) gives continuous brake rating both in hp-second per minute and in watts.

starts under load exceeds four to six per hour, and/or (2) the starting time exceeds 20 seconds. Similarly, the brake should be checked for thermal requirements when: (1) The number of stops exceeds four per minute, and/or (2) more than three seconds of stopping time are required.

Precautions for Overhauling Loads

When overhauling loads are encountered and no other but motor information given, it is well to consider a brake torque equal to the maximum or breakdown torque of the motor, which NEMA standards for normal-torque motors list as 200 to 300 percent of full-load motor torque. The brake will then be able to hold any load the motor is able to raise, regardless of any under-motoring or over-loading condition and still have a safety factor of twice the friction drag of any gearing involved. Furthermore, the larger the brake torque on overhauling loads, the shorter the time of stop, which decreases the potential energy given up by the load in changing its height. This results in less energy to be absorbed by the brake as heat during the stop. If brake torque plus friction drag is allowed to decrease to a value equal to or less than the overhauling torque, there is no net torque available for stopping the load. As the load descends, the brake becomes progressively hotter. Continued operation under these conditions may cause brake failure and consequent danger of load droppage.

Selection of Brake by Thermal Capacity

When complete data regarding a motor brake application are available, selection on the basis of thermal capacity is preferable to the full-load motor-torque method. Three system constants are required: (1) The inertia (Wr^2) of the rotating parts, (2) the speed from which the stop is made, and (3) the number of stops per minute. The first two of these constants can usually be obtained from the manufacturer of the driven machine, while the third is generally a matter of user preference. From these values, the exact stopping time, the hp-sec per one stop as peak thermal input to the brake, and the hp-sec per minute as average thermal input to the brake, can be determined.

The series of curves shown in Figs. 2, 3 and 4 save calculations by showing graphically the resultant brake size and stopping time for the usual case involving rotary motion only on non-overhauling loads. In Fig. 2, values for hp-sec per stop are plotted against inertia (Wr^2) and speed (rpm). When the hp-sec per stop has been determined, this number is located on Fig. 3, where it is combined with the number of stops per minute desired to determine the thermal rating of the brake necessary for the job. The value for hp-sec per stop is also used on Fig. 4 to obtain the exact stopping time of the load when braked from nominal rated motor speeds to rest, using any of the standard motor-mounted brakes intended for NEMA frame sizes 203C to 326C.

The curves in Fig. 2 are based on the following relationship, where Wr^2 is the lumped moment of inertia of rotating parts, including load and motor rotor, in lb-ft²; and N is the rpm from which the motor and connected load are to be brought to rest:

$$\text{Hp-sec stop} = \frac{\text{Kinetic Energy (ft-lb)}}{550} = Wr^2\left(\frac{N}{1{,}800}\right)^2 \qquad (1)$$

The Wr^2 value consists of the total weight of the rotating mass in pounds, times the mean radius of gyration in feet, squared. This total can be calculated as the summation of several small Wr^2 values when all are rotat-

ing at the same speed. If this is not practical, each separate Wr^2 can be plotted on Fig. 2 to find the hp-sec per stop of the part at its particular speed, and the summation of the several hp-sec-per-stops taken as the total energy per stop.

To illustrate the thermal capacity method of brake selection, a non-overhauling load has the following constants: Inertia of driven machine is 0.8 lb-ft² and of motor rotor is 0.4 lb-ft² totaling 1.2 lb-ft²; 11 stops per minute are to be made from speed of 1,750 rpm.

From Fig. 2 the hp-sec per stop is 1.1. Applying this value to Fig. 3 for 11 stops per minute, it is found that a brake rated at 12 hp-sec per minute is suitable if the stopping cycle were continuously repeated. Considering the variation among manufacturers, this thermal rating might correspond to a brake having a 10, 15 or 25 lb-ft torque rating. Beginning in the upper left hand corner of Fig. 4 with 1.1 hp-sec per stop, then moving down vertically to the 1,750 rpm speed line, and finally horizontally to the three brake torques listed just above, three different stopping times are located: 0.27 sec for 25 lb-ft brake, 0.44 sec for 15 lb-ft brake and 0.66 sec for 10 lb-ft brake, all of which can be termed satisfactory for general-purpose work.

If the usual three percent slip between no-load and full-load speed is neglected and the load considered as being stopped from 1,800 or 3,600 rpm, Eq (1) provides a quick rule of thumb for these two standard a-c motor speeds. The key relationships resulting from substitutions in Eq (1) are: One hp-sec per lb-ft² when stopping from 1,800 rpm, and four hp-sec per lb-ft² when stopping from 3,600 revolutions per minute.

Additions for Linear Motion

When horizontal linear motion accompanies movement of the rotating mass, the hp-sec per stop for linear motion alone is:

$$\text{Hp-sec/stop} = \frac{\text{Kinetic energy (ft-lb)}}{550}$$

$$= \frac{0.5\,MV^2}{550} = \frac{W_1\,V^2}{35{,}400} \quad (1)$$

where M is the mass of that part of the machine in linear motion, or more conveniently substituted as W_1, the weight in pounds of that part in linear motion; and V is the velocity of linear motion in feet per second.

The energies of rotary and linear motion are then added: Hp-sec per stop for rotary motion from Fig. 2 and hp-sec per stop for linear motion from Eq (1). The total hp-sec per stop is then plotted on Fig. 3 to find the brake thermal capacity required, and on Fig. 4 to find the stopping time. The distance traveled by that part of the machine in linear motion is:

$$S = \tfrac{1}{2}\,V\,t \quad (2)$$

where S is distance traveled, in feet and t is time of stop, in seconds, from Fig. 4.

Continuing the sample calculation used above wherein the total Wr^2 of the rotating parts is 1.2 lb-ft² and the speed from which the stop is to be made is 1,750 rpm, there are the following additional data: Stops per minute required by user, *nine*; weight of load in linear motion, 1,000 lb; and speed of linear-motion load, 5 ft per second.

The hp-sec per stop for rotary motion from Fig. 2 is 1.1 hp-sec and from Eq (1) for linear motion is

$$\frac{1{,}000\,(5)^2}{35{,}400} = 0.7 \text{ hp-sec}$$

The total hp-sec per stop thus becomes 1.8 hp-seconds.

Combining nine stops per minute and 1.8 hp-sec per stop on Fig. 3, the brake thermal capacity required for continuous stopping duty is 16 hp-sec per minute, or 200 watts. This brake is available in a torque rating of 50 lb-ft which has a stopping time at 1.8 hp-sec per stop, Fig. 4, of 0.22 second. The distance traveled by the 1,000 lb. weight during the stop, Eq (2), is:

$$S = \tfrac{1}{2} \times 5 \times 0.22 = 0.55 \text{ ft}$$

Overhauling Loads

For loads that, having been brought to rest, still invite motion of the motor drive in the same direction as is true of a loaded crane hook being power lowered, the motor-brake becomes primarily a holding brake. On large installations, a separate brake is often installed for stopping purposes. On the small jobs, however, where the functions of stopping and holding are combined, the brake must absorb on descent not only the kinetic energy of the rotary and linear motion, but also the potential energy given up by the weight on the hook, due to its change of height. This potential energy is equal to W_1 pounds of weight on the hook which has traveled S feet downward during the stop, making W_1S lb-ft of potential energy to be absorbed by the brake as additional heat during the stopping period.

The total hp-sec per stop of a descending overhauling load, compared to that of the same load not overhauling, is therefore a ratio larger than unity and can be shown as

$$\frac{T_b}{T_b - T_o} \quad (3)$$

where T_b is the brake torque and T_o is the overhauling torque, referred to motor shaft. This is a case where the overhauling torque is fixed by the application. The larger the brake torque, the less energy the brake must absorb per stop, the minimum being the kinetic (rotary and linear motion) energy of the system. Expressed in terms of system constants

$$T_o = \frac{\text{overhauling torque at drum}}{\text{gear ratio}}$$

or

$$T_o = \frac{9.55\,W_1\,V}{N} \quad (4)$$

where W_1 is the weight in lb of the overhauling portion of the load, V is the linear speed of descent in ft per second and N is the rpm of the motor.

When overhauling loads are encountered, the first step is to calculate the overhauling torque of the load, referred to the motor shaft. The brake torque must of necessity be larger than this overhauling torque in order to stop or hold the load. A value of 150 percent or larger is general practice.

Picking up once again the sample calculation above, an overhauling load has the following constants: Wr^2 of motor rotor and gear box, 1.2 lb-ft²; motor speed, 1,750 rpm; type of stopping duty, intermittent; rated load on hook, 1,000 lb; and lowering speed, 5 ft per second.

From Eq (4), the overhauling torque is

$$T_o = \frac{9.55 \times 1000 \times 5}{1{,}750}$$

$$= 27.3 \text{ lb-ft.}$$

Referring to the 50 lb-ft brake selected above, the total kinetic energy per stop of 1.8 hp-sec remains unchanged, regardless of the brake torque selected. Total hp-sec per stop for overhauling during descent is, however

$$1.8\left(\frac{50}{50 - 27.3}\right) = 4 \text{ hp-sec/stop}$$

The stopping time for the 50 lb-ft brake from Fig. 4 is 0.48 sec and the drift downward of load during stop, from Eq (3) is

$$S = \tfrac{1}{2} \times 5 \times 0.48 = 1.2 \text{ ft}$$

Since the thermal rating of this 50 lb-ft brake is 16 hp-sec per min, continuous, or 24 hp-sec per min, intermittent (one hour), the allowable rate of

stops per minute is 24/4 or *six*, which is usually sufficient. In this instance, the motor is 10 hp at 1,750 rpm with a full load torque of 30 lb-ft. The brake, therefore, has 167 percent of full-load motor torque.

Although not critical, if it is necessary to figure the action of the brake stopping an ascending load, Eq (3) is replaced by

$$\frac{T_b}{T_b + T_o}$$

for overhauling and the overhauling torque assists the brake in stopping. Total brake hp-sec per stop for overhauling during ascending, is

$$1.8\left(\frac{50}{50 + 27.3}\right) = 1.16 \text{ hp-sec}$$

The stopping time, for the 50 lb-ft brake from Fig. 4 is 0.14 sec and the drift upward of load during stop from Eq (3) is

$$S = \tfrac{1}{2} \times 5 \times 0.14 = 0.35 \text{ ft}$$

For an additional refinement, the friction of the gear-box can be taken into account. T_o as calculated above must then be multiplied by the decimal efficiency of the gear-box, which is approximately 0.9 for the ordinary case. For the example given above, the change is negligible.

Effects of Excessive Peak Input

It is possible to conceive of a high-inertia load having a hp-sec per stop value of say 40, which is to be stopped once every four minutes. Although the average input to the brake is 10 hp-sec per minute, a brake applied on the basis of this average value deteriorates rapidly. The friction disks become heated to a higher-than-normal temperature during the prolonged stop, causing standard organic binders to bake out. This results in high disk wear and galling of the plates the disks rub against. For good brake life, the peak input should not exceed approximately 1.5 times the continuous brake rating. This also means that the rate of stops per minute in an application where the cycle time is erratic should not be more than 1.5 times the average number of stops required per minute; otherwise the brake must be figured on a peak load basis.

The equation upon which Fig. 4 is based is

$$t = \frac{10{,}500 \times \text{hp-sec per stop (brake)}}{N\ T} \qquad (5)$$

where t is time of stop in seconds, N is the rpm from which stop is made and T is brake torque in pound-feet. This relationship can be used for on-the-job checking of the loading of a brake. The stopping time of brakes that are approaching the overloaded condition per stop can be clocked with a stop watch, as can the number of stops per minute. Then

$$\frac{t\ N\ T}{10{,}500} = \text{hp-sec/stop} \qquad (6)$$

which should not be more than 1.5 times the brake continuous rating. Also for good brake life, Eq (6) times maximum rate of stops per minute becomes the maximum hp-sec per minute which should not exceed 1.5 times the brake continuous rating.

Speed of Response

Rapid release and quick setting are ordinarily desirable features in a motor-mounted brake. The former allows the motor to start without restriction and the latter is important in controlling the drift of the load during the stop. Any delay between removal of brake power and actual setting of the brake allows the load to rotate at practically full speed, while during braking, the average speed is half the full speed. Therefore, if the delay in setting is as much as one half the actual braking time, the total time of stop is only 1.5 times normal, but the drift of the load is twice normal. The a-c direct-acting brake responds more rapidly compared to the solenoid types, because the magnet stroke is seldom more than 0.05 in. and there are no mechanical linkages.

A relatively long-fixed delay time is sometimes desirable in a holding brake to allow a second (stopping) brake to reduce the system speed to nearly zero before the holding brake is applied. The d-c brake, although normally designed for quick response and intended for use with d-c motors, is easily adapted to long delay time through magnetic and electrical circuit design. The d-c unit will operate as a shunt brake from any suitable d-c supply, such as a small rectifier, in the event there is an a-c power supply.

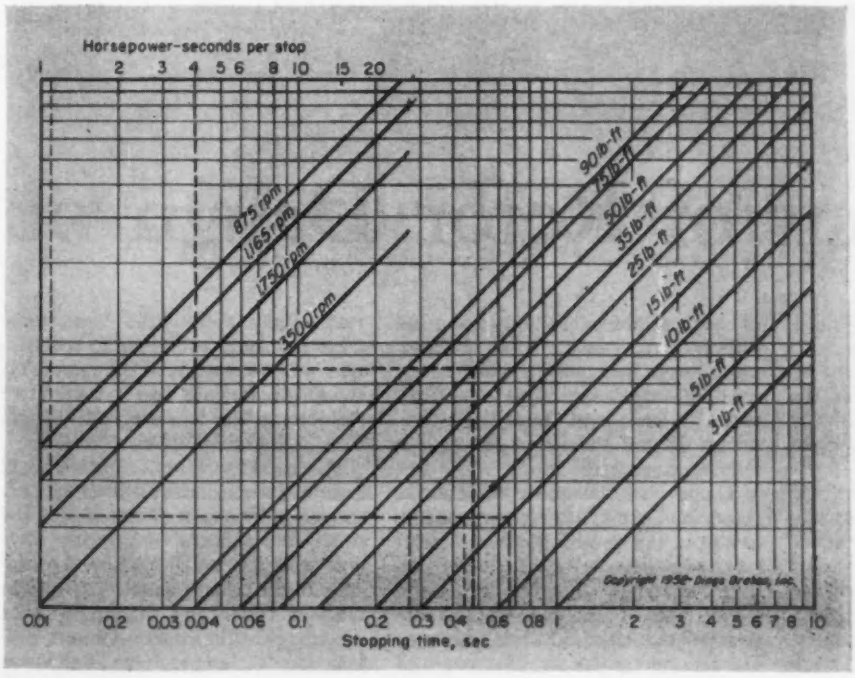

Fig. 4—Horsepower - seconds per stop (1.1) from Fig 2 and speed from which stop is made (1,750 rpm) determine stopping time for any standard brake torque—0.27, 0.44 and 0.66 sec for 25, 15 and 10 lb-ft brakes, respectively.

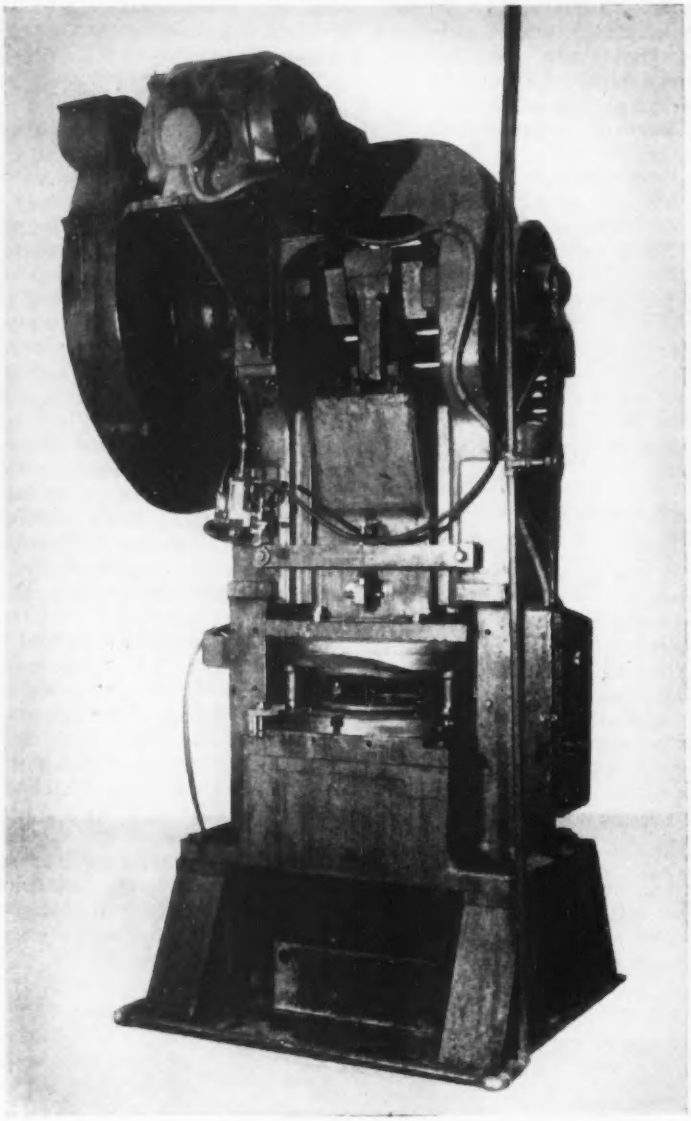

Table I—NEMA Standards

	DESIGN A
Slip at Full Load	Less Than 5%
Locked Rotor Torque	Section A
Pull-up Torque	See Note
Breakdown Torque	More Than Section C
Locked Current	More Than Section F

Hp	Section A — Locked-Rotor Torque — No. of Poles							
	2	4	6	8	10	12	14	16
½	—	—	—	150	150	115	110	105
¾	—	—	175	150	150	A	A	A
1	—	275	175	150	150			
1½	175	265	175	150	150			
2	175	250	175	150	145			
3	175	250	175	150	135			
5	150	185	160	130	130			
7½	150	175	150	125	120			
10	150	175	150					
15	150	165	140					
20	150	150	135					
25	150	150	135					
30	150	150	135					
40	135	150	135					
50	125	150	135					
60	125	150	135					
75	110	150	135					
100	110	125	125					
125	100	110	↓	↓	↓	↓	↓	↓
150	100	110						
200	100	100						

(Left) Peculiar characteristics of squirrel-cage Type D motor make it suitable for punch press drive with flywheel storage.

Effects of Rotor Design on

F. A. LIST
Westinghouse Electric Corporation

OPERATING CHARACTERISTICS of d-c motors are determined principally by the arrangements of the field circuits. In contrast to this, the field or stator circuits of all three-phase, integral horsepower a-c motors are substantially the same. Rotor construction is the variable that makes the performance of polyphase motors differ.

The stator or field of the polyphase induction motor has three windings, each of which is connected across a leg of the three-phase line. The rising and falling currents in the winding set up a magnetic field. This field is not fixed in space as it would be if d-c excitation were used. Instead, the field rotates around the stator structure at synchronous speed.

The revolving magnetic field cuts the rotor conductors, setting up voltages in them. The resulting rotor currents react with the revolving field and produce torque.

The rotor of a polyphase motor consists of the electrical iron, the conductors and insulation. Although all rotors have these same basic parts, there are many variations in construction. In the squirrel cage motor, the conductor bars are laid axially across the rotor. The bars are recessed into slots in the laminated electrical iron.

All conductors on a squirrel cage rotor are mechanically and electrically connected by means of end rings. The conductors and end rings make up a unit structure bearing some resemblance to an actual squirrel cage. The cage of conducting material can be die cast onto the rotor. Another construction technique frequently em-

for Three-Phase, Integral Horsepower Motors

DESIGN B	DESIGN C	DESIGN D	DESIGN F	WOUND-ROTOR
Less Than 5% Section A See Note Section C Section F	Less Than 5% Section B See Note Section D Section F	5% Or More 275% Section F	Less Than 5% 125% 135% Section G	Section E

Section B			Section C					Section D				Section E			Section F		Section G
Locked-Rotor Torque			Breakdown Torque					Breakdown Torque				Breakdown Torque			Locked Amps @ 220 Volts		Locked Amps @ 220 Volts
No. of Poles			No. of Poles					No. of Poles				No. of Poles			B, C, D	B	
4	6	8	2	4	6	8	10	2	4	6	8	4	6	8	60 Cyc	50 Cyc	60 Cyc
—	—	—	—	—	—	250	200	—	—	—	—	—	—	—	12	14	—
—	—	—	—	—	275	250		—	—	—	—	—	—	—	18	21	—
—	—	—	—	300	275	250		—	—	—	—	—	—	250	24	28	—
—	—	—	275	300	275	250		—	—	—	—	—	—	250	35	40	—
—	—	—	250	275	250	225		—	—	—	—	275	275	250	45	50	—
—	250	225	250	275	250	225		—	—	225	200	275	275	250	60	70	—
250	250	225	225	225	225	225		—	200	200	200	275	275	250	90	105	—
250	225	200	215	215	215	215		—	190	190	190	275	250	225	120	140	—
250	225		200	200	200	200		—				275	250	225	150	175	—
225	200							190				250	225	225	220	255	—
200												225	225	225	290	335	—
															365	420	—
															435	500	270
															580	670	360
															725	835	450
															870	1,000	540
															1,085	1,250	675
															1,450	1,670	900
															1,815	2,090	1,125
															2,170	2,495	1,350
															2,900	3,335	1,800

Torques in percent of full load torque with rated voltage and frequency applied. The values of torque listed are the minimum values. Locked rotor current for three-phase motors designed for voltages other than 220 v shall be inversely proportional to the voltage. The values of currents listed are the maximum values. With rated voltage and frequently applied, the pull-up torque of design A, B, and C motors shall not be less than 70 percent of the tabulated locked-rotor torque, but in no case less than rated full-load torque. Motors with 10 and more poles may slip slightly greater than 5 percent.

A-C Motor Performance

ployed is the fabrication of the cage by brazing or welding. This, of course, is done after the conductors are positioned in the rotor slots.

Little electrical insulation is needed.

Despite its simple construction, the squirrel cage motor can be built to provide a variety of operating characteristics. Designs of the most commonly used types of squirrel cage motors have been standardized by the National Electrical Manufacturers Association. NEMA Designs A, B, C, D and F are the designations of the principal types of integral horsepower squirrel cage induction motors. The torque ratings and the locked rotor current are the characteristics that distinguish one NEMA Design from another.

In Fig. 1, the speed-torque curves of the five types of squirrel cage motors are given. The distinctions between the various motors are obvious. The maximum breakdown torque developed by any given type of motor is related to its alphabetical order. Thus, the speed of the Design A motor is least affected as torque is increased, while the speed of the Design F is the most sensitive to torque changes.

Design A Motor

According to NEMA Standards, the Design A motor is a squirrel cage motor suitable for full voltage starting and developing the values listed in Table I for locked rotor torque, pull-up torque and full load slip.

For the Design A motor, NEMA does not specify the exact values of breakdown torque (the maximum torque a motor can exert at rated voltage and frequency without an abrupt drop in speed) or locked rotor current. Instead, NEMA requires that the

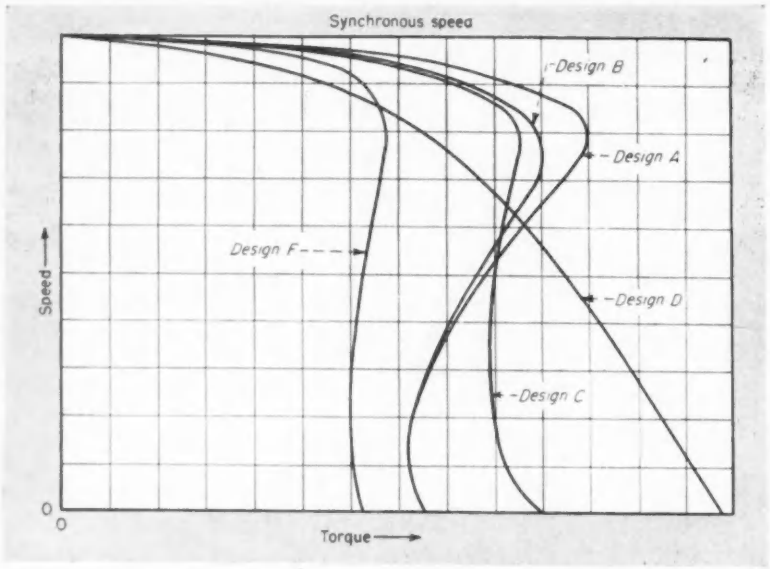

Fig. 1—Typical performance curves for induction motors. Breakdown torque is the maximum value of torque developed before an abrupt drop-off in speed.

ratings for these quantities be "in excess of values shown for Design B" motors.

The rotor slots on most Design A motors are similar to the slots in Fig. 2. The cross-sectional area of the slots is quite large so that rotors with this type of slot have a relatively high thermal capacity. The slot extends deep into the punching and is narrow. The deep bar effect in this slot is moderately great. This means that during starting and for low speeds of the rotor, the current is crowded into the upper part of the slot. This phenomenon produces a high effective resistance and low reactance in the conductor in the slot. As the motor speeds up, the current tends to distribute itself through the entire cross-section, thus giving a lower effective rotor resistance at running speeds.

The high effective rotor resistance is an advantage during starting since developed torque is proportional to resistance. At the same time, high rotor resistance is undesirable at full load because high resistance produces a correspondingly high power loss and causes the motor to run at increased slip. Slip is the difference between synchronous speed and full load speed, expressed as a percentage of synchronous speed. The deep slot construction of the Design A motor yields the beneficial combination of high starting torque, good full load efficiency and slip of less than five percent.

As far as rotor construction is concerned, the Design B is quite similar to the Design A motor. However, in the latter, a strong field is used to achieve a high breakdown torque. While providing desirable torque characteristics, the strong field has the disadvantage of causing locked rotor currents that are high in comparison to those of the Design B motor.

Design A motors are recommended for the following applications:

1. Single start, high inertia loads where good running performance is needed.

2. Energy storage (flywheel) applications where load pulsations are rapid.

3. Machines requiring breakdown torques in excess of Design B values.

Some specific products that can benefit by the use of Design A motors are fans, centrifuges, rubber mill drives, hammer mills, band saws and slusher hoists.

This type of motor is generally not suited for:

1. Applications requiring more torque from the motor than the motor can develop. Since NEMA has not standardized the exact values for the breakdown torque, the motor manufacturer should be consulted regarding the capabilities of the motor.

2. Applications where minimum or standard locked rotor current is needed.

3. Energy storage (flywheel) applications where load pulsations are quite slow. When accelerating or developing high torques, this motor is subject to considerable heating because of the excessive current drawn.

4. Single start high inertia loads where the accelerating time is very long.

5. Applications requiring extremely heavy starting, dynamic braking, and plugging duty cycle.

Design B Motor

This type of squirrel cage machine is the standard or general purpose motor of industry and is used in the greatest numbers. Its rotor construction is along the lines of those sketched in Fig. 2 for the Design A motor. The Design B motor, however, is distinguished by its lesser value of field excitation. Both breakdown torque and locked rotor current are correspondingly lower. The characteristics specified by NEMA for the Design B motor are listed in Table I. The motor has fairly high locked-rotor and break-

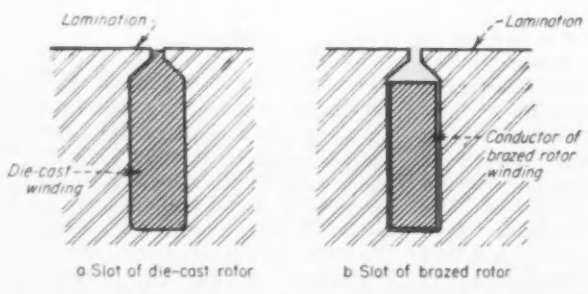

Fig. 2—Slot and conductor cross section of NEMA Design A and Design B motors. Rotor bars are deep. During starting and at low speeds, current is crowded in top of bars. Thus, values of effective resistance and developed torque are high.

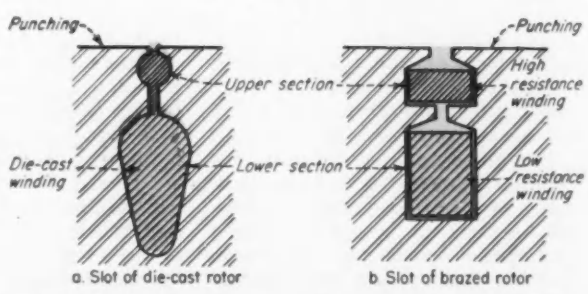

Fig. 3—Slot and conductor cross section of NEMA Design C and Design F motors. This is called a "double-deck" slot. At low speeds, most of the rotor current is carried by the upper conductor. Effective resistance is high, but thermal capacity is low.

down torques. The locked rotor current is low and running performance is good. Slip at full load is less than five percent. On most general applications, the Design B is the motor to use.

Among the successful applications are: blowers, bottling machines, buffers, compressors (unloaded start), concrete mixers, crushers, dishwashers, irrigation pumps, machine tools, centrifugal pumps, stokers, weaving machines, lineshafts, hammer mills, hay balers and woodworking machines.

Design B motors are not generally recommended for the following types of applications:

1. Accelerating high inertia loads.
2. Heavy duty cycles of starting, dynamic braking and plugging.
3. Loads with energy storage systems such as the punch press, where the energy is stored in the fly wheel for peak loads.

Design C Motor

The Design C motor is a squirrel cage machine developing extremely high locked-rotor torque. The rotor slots on this type of motor are similar to those pictured in Fig. 3. The slot extends deep into the punching and has two enlarged sections. This slot is sometimes referred to as a "double-deck" slot.

The deep bar effect in this type of slot is very great. This is brought about by the fact that at all times the amount of flux threading the lower portion of the conductor is greater than that passing through the upper portion. Thus, the inductive reactance of the lower part is proportionately greater.

Now, when the rotor is at standstill or moving slowly, the rotating magnetic field generates voltages of relatively high frequency in the rotor bars. The inductive reactance, which is a function of frequency, is also high. In fact, at the upper slip frequencies almost all of the opposition to current flow in the rotor bars is supplied by inductive reactance. Logically, then, the current tends to crowd into the upper portions of the rotor bars, which as mentioned above, always exhibit less inductive reactance than the lower sections.

Being smaller in diameter, the upper section of the bar has greater ohmic resistance than the lower section. And developed torque is proportional to ohmic resistance. Thus, at starting when the rotor currents are crowded into the upper deck of the bar, torque is high.

As the rotor speeds up, the slip frequency drops until inductive reactance throughout the entire cross-section of the bar becomes neglible. Then, the current tends to distribute itself evenly throughout the depth of the bar. Therefore, at running speeds the ohmic resistance of the bar is reduced by virtue of the increase in the effective cross-sectional area. Power losses are thus minimized when the motor is operating at rated speed. Full load efficiency is good.

Since most of the current is crowded into the small upper section of the slot during starting and at low speeds, the current density in this section is very high. These densities can be tolerated for only a short length of time. Otherwise, the conductor in the upper section of the slot becomes overheated and is subject to failure. It can, therefore, be said that the thermal capacity of a rotor with this type of slot is low during starting and accelerating.

The operating characteristics specified by NEMA for the Design C motors are given in Table I.

It is seen from this table that there are no standards for the Design C motor on three horsepower, four pole and below. The reason for this is that Design B motors in these horsepower ratings have very high locked-rotor torques, thus making the Design C motor unnecessary.

The Design C motor has very high locked-rotor torque. The thermal capacity of the rotor during starting is low as previously outlined and this type of motor should not be used on applications where long accelerating times are involved. The Design C motor is best applied where the starting torque requirement is high but of a static nature such that when the motor starts, it can rapidly accelerate to full load. The Design C motor has moderately high breakdown torque and good running efficiency. Slip is less than five percent at full load.

Some specific applications are electric stairways; plunger pumps; conveyors having low inertia but requiring high starting torque because of static friction; and, compressors with no unloading device and without excessive flywheel effect.

Design D Motor

As sketched in Fig. 4, the slot of this type of squirrel cage motor extends only a moderate distance into the punching and has a small cross-section. Because of the small cross-section of the bars, the rotor resistance is quite high both during starting and running. The deep bar effect in this design is slight. Therefore, the effective rotor resistance is essentially the same from zero speed to synchronous speed.

The outstanding characteristic of the Design D motor is the large value of torque developed as a result of the high rotor resistance. This is true not only of starting torque but of running torque as well, because as explained above the rotor resistance does not change appreciably with speed. But, for the same reason, the Design D motor has relatively low full load efficiency and a slip that is generally more than 5 percent.

The high resistance of the conductors keeps rotor currents to a minimum. Thus, although the conductor cross-section is small, current density is low. The resulting thermal capacity of the rotor is large during starting and running so that the Design D motor is

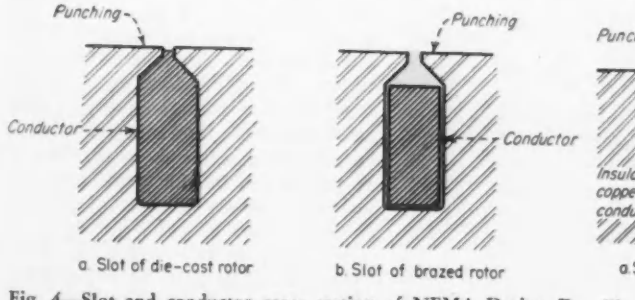

Fig. 4—Slot and conductor cross section of NEMA Design D motor. Area of bar is small and ohmic resistance great. Rotor currents are kept small so that thermal capacity is comparatively large. Both starting and running torques are high.

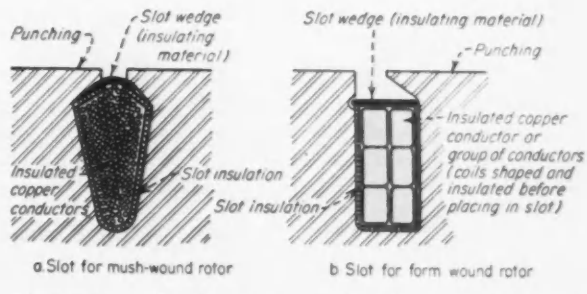
Punching
Slot wedge (insulating material)
Insulated copper conductors
Slot insulation
a. Slot for mush-wound rotor
Slot wedge (insulating material)
Punching
Insulated copper conductor or group of conductors (coils shaped and insulated before placing in slot)
Slot insulation
b. Slot for form wound rotor

Fig. 5—Slot and conductor cross section of wound rotor motor. The insulated conductors are laid into the slots in layers. Construction costs of the wound rotor motor are higher than for an equivalent rating of squirrel cage motor.

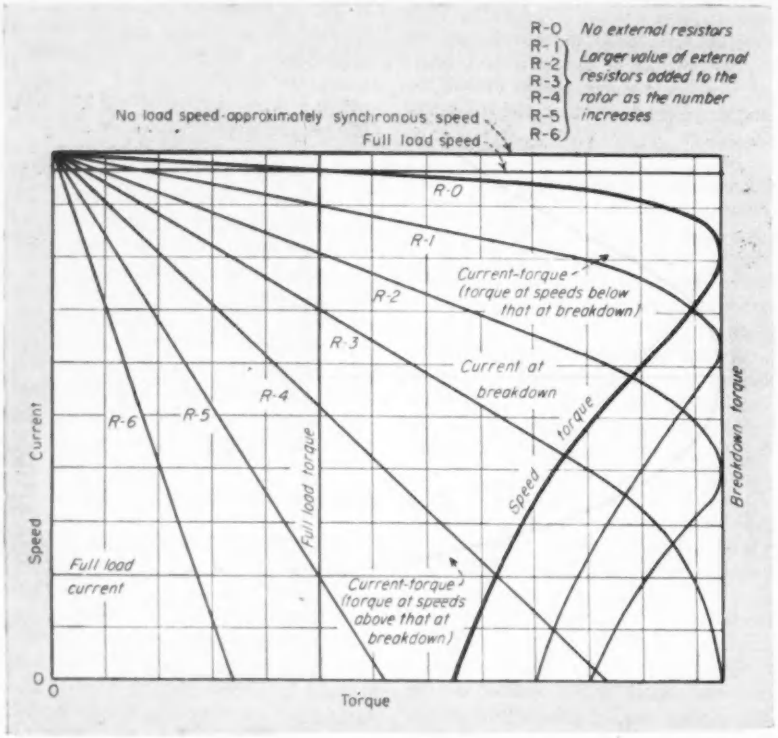

Fig. 6—Theoretical performance curves for the wound rotor motor. Note that both the breakdown and locked rotor torques decrease as resistance is added.

suited to loads of high inertia.

Its characteristics make this type of motor suitable for use on energy storage systems, such as the flywheel drive of a stamping press. Since the slip is high, regulation is poor. Thus, when the flywheel slows down at the moment of peak load, the motor will not attempt to carry an overload. The motor slows with the flywheel, delivering substantially constant torque at all speeds. This prevents large electrical losses in the motor.

On the other hand, a Design B with low slip and good regulation runs at fairly constant speed over wide ranges of load. Thus, this type of motor is relatively unsatisfactory for flywheel drives. Whenever a heavy load tended to reduce the speed of the flywheel, the motor would attempt to keep the speed from changing by assuming an overload. Such overloaded conditions are destructive to the motor, lower its efficiency and may have undesirable effects on the power supply.

The full load efficiency of the Design D motor is not as good as the full load efficiency of the Design B motor. Still the overall efficiency of the former is greater than the overall efficiency of the design B motors. This is so because the peak current requirements for the Design D motor are smaller in such applications.

The operating characteristics of the Design D motor are given in Table I. The speed-torque performance curve for this motor is shown in Fig. 1. The outstanding feature is the absence of a definite breakdown point.

The Design D motor is recommended for the following:

1. Applications requiring acceleration of relatively high inertia loads.
2. Applications requiring high starting torque.
3. Applications where stored energy is used.
4. Applications where the duty cycle is predominately starting, dynamic braking and plugging.

Specific uses include punch presses, hoists, shovels, crushers, valve operators, oil well pumps, elevators and conveyors having high inertia and static friction.

The Design D motor should not be selected where good full load efficiency or large torques at fast speeds are required.

Design F Motor

The applications for the Design F motor are more limited than any of the squirrel cage machines described up to now. It is a large machine. As noted from Table I, NEMA specifications for this motor are listed only for sizes from 30 hp and upward.

The motor is designed for use on fairly low capacity power systems—systems that are capable of carrying the running load of the motor but that are adversely affected by high currents. Therefore, the chief feature of the Design F motor is that it draws full load and locked rotor currents that are small in comparison with the Design B motor. But low torque goes hand in hand with small locked rotor current and it is this factor that restricts the usage of the NEMA Design F motor.

The magnitude of rotor currents in the motor is held down by the adoption of "double-deck" slot construction. This slot is quite similar to that sketched in Fig. 3 for the Design C motor. However, the resistance of the rotor bars per unit of length is considerably greater in the Design F motor. As pointed out previously, the use of a double-deck slot produces a rotor with a low thermal capacity during starting and accelerating.

The speed-torque curve for the Design F motor is included in Fig. 1. It has a medium locked rotor torque and a low breakdown torque when compared to the Design B motor. In addition, the Design F machine has poorer running efficiency and power factor. Slip is less than five percent.

From the point of view of application, NEMA standards for the Design F motor do not seem to have the correct correlation between breakdown torque and locked rotor torque. In most uses, a motor meeting the requirements for NEMA Design F either could not start the load; or, could start the load but would pull out of synchronism on peak loads. This is so because the locked rotor and breakdown torques specified for this motor are substantially the same. Thus, when a Design F motor starts a machine and carries its peak load satisfactorily, it usually will be found that the locked rotor torque required for the load is much less than that specified by NEMA for the motor. In other words, the Design F motor is seldom or never called upon to deliver the locked rotor torque that NEMA requires to be built into it. If a reduction in locked rotor torque for the same locked rotor current were allowed by NEMA a single deck rotor slot could be used, yielding a higher thermal capacity and better efficiency.

Design F motors are used only where the power supply is of limited capacity; where the torques available from the motor are sufficient to start and run the load; and, where the starting and accelerating duty cycles are light.

Design F motors are not generally recommended for the following types of applications:

1. Those requiring more from the motor than NEMA specifies for the design and rating. When NEMA specifies no standards, manufacturers recommendations should be followed.
2. Applications requiring long accelerating time.
3. Loads requiring frequent accelerations or frequent plugging.
4. Applications where Design B currents are objectionable.

Wound Rotor Motors

The principles of operation of this type of motor are the same as those of the squirrel cage induction motor. However, in place of the short-circuited bars, the rotor carries insulated copper conductors that are properly wound or arranged to form electrical poles. The electrical windings terminate in slip rings leading to external circuits.

The rotor slots on most wound rotor motors are similar to those sketched in Fig. 5. The current is not distributed through the entire cross section of the slot but travels through the copper wire. The slot is shaped primarily to facilitate winding, not to give the deep bar effect as in the various types of squirrel cage motors.

The main advantage of the wound rotor is that external resistance can be added to the rotor circuit via the slip rings. By changing the value of this resistance, the motor speed can be adjusted over a wide range while keeping the developed torque constant.

The theoretical performance curves for the wound rotor motor are given in Fig. 6. Note that both the breakdown and locked-rotor torque decrease as resistance is added, while the breakdown torque is substantially constant. However, when the motor is running, speed can be adjusted without affecting operation of the load. For starting high inertia loads, most of the external resistance should be cut out of the rotor circuit.

The curves of Fig. 6 are true only if the added resistors are pure resistance (exhibiting no inductance or capacitance effects) and providing that the values of resistance in each of the three phases are equal. Actually, there is some reactance in most external resistors and seldom are the values of these resistors exactly balanced. Accordingly, as shown in Fig. 7, there is some decrease in breakdown torque as the speed at which breakdown occurs is lowered.

The advantages of this type motor over a squirrel cage rotor are two-fold. (1) The rotor resistance can be changed to give a wide range of motor speed while developing a certain torque, whereas the rotor resistance in a squirrel cage rotor is fixed. (2) The resistance of the rotor winding is quite low and the external resistors absorb most of the power loss in the rotor circuit. Thus, much of the motor loss is separated from the motor. This is an advantage especially at low speeds. In the squirrel cage rotor, all of the motor losses are confined to the motor structure itself. Therefore, heating during acceleration, reversals, plugging and dynamic braking is more critical in squirrel cage than in wound rotors.

As an example of wound rotor operation, consider the starting of a high inertia load. At the start, the external resistance added is of a value high enough to limit line current, and yet low enough to give a satisfactory ratio of locked torque to current. As the load speeds up, the external resistance is reduced to maintain the same torque—current ratio. One advantage of the wound rotor motor in this application is that the starting current can be adjusted to the full load value. Thus, there is no problem of high starting currents. The rotor losses during acceleration of the high inertia load are dissipated principally in the external resistors. Therefore, the temperature rise of the motor is less than that of a squirrel cage motor used to drive the same load.

When compared to the squirrel cage motor, the wound rotor motor has several disadvantages also. Because of the more involved rotor construction, the cost of the wound rotor motor is greater than that of the squirrel cage. The fact that insulation is required over the rotor windings adds to the cost, bulk and weight of the motor. And, contributing to cost and bulk, also, are the external resistors and controls that are peculiar to operation of the wound rotor motor.

The cast or brazed squirrel cage structure is, of course, more rugged than the wound rotor. In addition, the squirrel cage motor has no slip rings, brushes or external resistors—which contribute to maintenance cost.

Wound motor rotors are recommended for the following:

1. Adjustable speed applications.
2. Applications requiring high locked rotor torque, low locked rotor torque, and good running performance that cannot be supplied by a squirrel cage rotor motor.
3. Applications with duty cycles, including starting, accelerating, dynamic braking and plugging, that are too severe for squirrel cage motors.

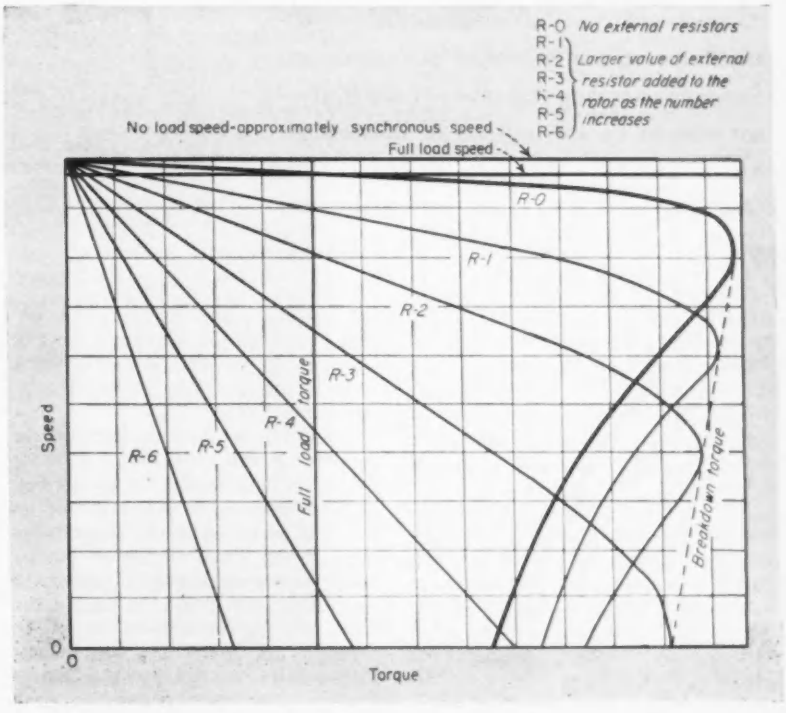

Fig. 7—Observed performance curves for a typical wound rotor motor. These curves differ from the theoretical in that they reflect the small amount of reactance that is present in most external resistors. The theoretical curves are based on the assumption that the external resistors are pure resistance.

Equivalent Dynamical Systems For Complex Vibration Problems

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Procedure for transforming complex structures into dynamically equivalent single-string lumped-mass systems with linear connecting springs for purposes of impact and vibration analysis. Influence coefficients obtained for statically loaded structures are converted to spring stiffnesses of the equivalent systems by solving sets of linear algebraic equations. Analogies for beams with loads replaced by concentrated masses.

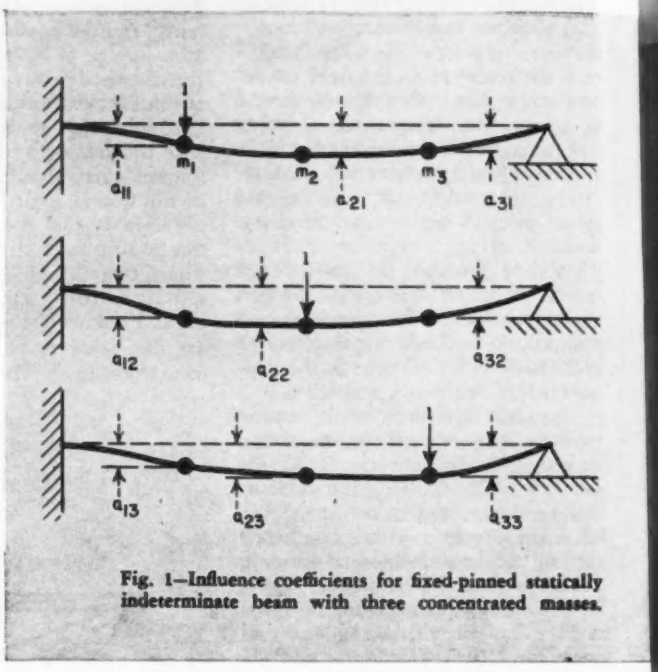


Fig. 1—Influence coefficients for fixed-pinned statically indeterminate beam with three concentrated masses.

EVALUATION OF THE EFFECTS of impact and vibration on stresses and deflections occuring in a machine, or its surrounding structure, is a much more difficult problem than that of designing for static loads alone. In general, various approximation procedures are used to obtain answers.

For simple elements, such as uniform single-span beams or shafts subjected to various end restraints, frequency formulas for the different modes have been tabulated and the mode shapes are well known (See Freberg and Kemler, "Elements of Mechanical Vibration," Second Edition, p 142). Most practical problems, however, involve beams of varying cross section with concentrated masses fastened to them here and there. Such beams, moreover, are frequently interconnected by bolted, riveted or welded joints to form more or less complex constructions. For these systems the available standard solutions do not apply.

To solve specific cases, perhaps the simplest of the approximate methods in general use is the energy method of Rayleigh, which makes use of an assumed plausible mode shape (frequently the static deflection curve) satisfying the support conditions of the structure. This method is usually restricted to the fundamental mode. In principle, the energy relations for the higher modes are equally valid, but in practice large errors usually accompany estimates of modes above the fundamental.

An extension of the energy method to higher modes has been developed by Ritz (See Timoshenko, "Vibration Problems in Engineering," Second Edition, p 370). It involves expressing the estimated mode shape in terms of two or more parameters, the values of which are finally set by minimizing with respect to each of the parameters in turn the expression for the frequency obtained from the conventional energy relations.

A method of successive approximations due to Stodola (See Den Hartog, "Mechanical Vibrations," Third Edition, p 202) also starts with an assumed deflection curve, which is modified over and over again until the deflection curve becomes compatible with the inertia loads imposed on the structure when vibrating with this shape. This iterative method always leads to the fundamental mode. It

may be used for determining higher modes also, but with much labor. In the successive approximations leading to some higher mode, the contributions of all the lower modes must be subtracted at the end of each cycle of iteration. The method, otherwise, will eventually lead back to the fundamental mode.

Influence Coefficients

The static deflection concept frequently used in the Rayleigh method, and to begin the Stodola method, is an obvious approximation to a dynamical mode shape. The static deflection

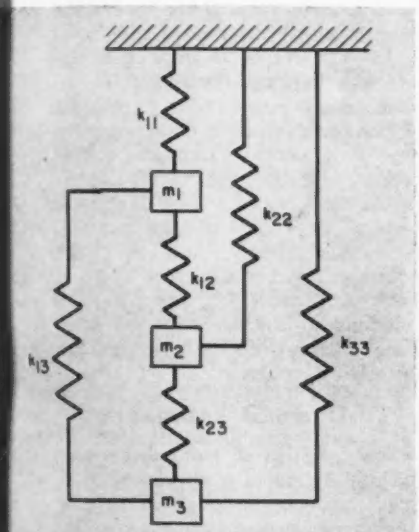


Fig. 2—Mechanical analog in which a system of three masses interconnected with springs represents three concentrated masses on a fixed-pinned beam.

properties of a structure, however, may still be used conveniently to set up an equivalent lumped spring-mass system, which may then be analyzed by simple methods for all the desired dynamical properties without going through the process of successive iterations. The equivalent lumped system will represent the original system to an accuracy dependent on the extent of the lumping. The more lumps, properly distributed, the more accurate the representation.

To demonstrate with an example the procedure for setting up and solving such an equivalent lumped system, consider the fixed-pinned statically indeterminate beam with three concentrated masses shown in Fig. 1. The distributed weight of the beam will be considered as negligible, although it might be taken into account by assigning appropriate fractions of it to the concentrated masses already present.

If a unit vertical force be applied in turn to each of the masses, vertical deflections of all three masses would take place in each case. The magnitude of a given deflection depends on the location of the unit force, on the support conditions, and on the distribution of flexural rigidity EI along the length of the beam. These are strictly statical properties of the beam. The nine deflections so obtained are the "influence" coefficients, they determine the influence of a load at any one location on the deflections at all locations.

For present purposes, the locations of interest are at the concentrated masses. This limitation does not destroy the generality of the problem because, for all practical purposes, heavy beams or shafts may be considered as made up of concentrated masses (each representing the mass of a short piece of beam) mounted at corresponding points on the weightless beam having the same flexural rigidity distribution and support conditions as the original beam. Influence coefficients would then be determined for unit forces applied at all such mass locations.

In the notation used in Fig. 1, the subscripts on the influence coefficients are arranged so that the first subscript indicates the point at which the deflection is being considered, while the second subscript indicates the point at which the corresponding unit load is applied. Thus, the coefficient a_{12} represents the deflection of mass 1 that results from a unit load applied at mass 2, while a_{21} represents the deflection of mass 2 that results from a unit load applied at mass 1. For small deflections (that is, for linear systems) the Maxwell reciprocity rule states that

$$a_{12} = a_{21},\ a_{13} = a_{31},\ a_{23} = a_{32}$$

so that actually only six independent influence coefficients are involved in Fig. 1, instead of nine.

Influence coefficients may be determined by the conventional processes of calculation used in static stress analysis. Frequently, the coefficients are obtained by direct measurement in static tests conducted on the given structure or on a model of the structure. However they are obtained, the following development will be premised on a knowledge of the influence coefficients for the structure. In the following discussion the beam of Fig. 1 will be used to represent the structure under consideration.

Equivalent Spring-Mass System

The three masses on the continuous beam of Fig. 1 can be represented by a mechanical analog consisting of a system of three masses interconnected with discrete springs, as shown in Fig. 2. The six interconnecting springs correspond to the six influence coefficients in the actual beam.

The spring constants k are related to the influence coefficients through simple linear algebraic equations obtained by writing the static equations of equilibrium for the entire system and for each mass, with unit force applied to each mass in turn. Thus, the three equations of equilibrium for the entire system are, under unit load,

$$\left.\begin{aligned} a_{11}k_{11} + a_{21}k_{22} + a_{31}k_{33} &= 1 \\ a_{12}k_{11} + a_{22}k_{22} + a_{32}k_{33} &= 1 \\ a_{13}k_{11} + a_{23}k_{22} + a_{33}k_{33} &= 1 \end{aligned}\right\} \quad (1)$$

The k terms in Eqs (1) can be computed by obvious numerical methods, by analogs (See "Resistance Network Analogue for Solving Vibration Problems," PRODUCT ENGINEERING, April 1951, p 103), or by high speed digital machines.

Applying the conditions of static equilibrium to each mass alone when under unit load,

$$\left.\begin{aligned} &a_{11}k_{11} + (a_{11} - a_{21})\,k_{12} + \\ &\quad (a_{11} - a_{31})\,k_{13} = 1 \\ &(a_{21} - a_{12})\,k_{21} + a_{22}\,k_{22} + \\ &\quad (a_{22} - a_{32})\,k_{23} = 1 \\ &(a_{32} - a_{13})\,k_{31} + \\ &\quad (a_{32} - a_{23})\,k_{32} + a_{33}\,k_{33} = 1 \end{aligned}\right\} \quad (2)$$

The relations in Eqs (2) are used to determine the cross stiffness.

Natural Frequencies and Modes

When the system of Fig. 1 vibrates in any one of its three natural modes, the masses m_1, m_2, m_3 will have amplitudes denoted by A_{1j}, A_{2j}, and A_{3j}, respectively; the first subscript indicating the mass in question and the second the natural mode in question (j equals 1, 2, or 3). The notation ω_j will be used to denote the corresponding natural frequencies.

In a natural mode the motion of each mass is sinusoidal, all masses reach maximum position simultaneously and they go through equilibrium position simultaneously. Thus, at an extreme displacement the entire system is momentarily stationary. At this point the inertia forces resulting from the three masses are $m_1\omega^2{}_j$, $m_2\omega^2{}_j$, $m_3\omega^2{}_j$. These are in equilibrium with the loads in the springs. The equilibrium equations are:

$$\left.\begin{aligned} &[m_1\omega_j^2 - (k_{11} + k_{21} + k_{31})]\,A_{1j} + \\ &\quad k_{21}A_{2j} + k_{31}A_{3j} = 0 \\ &k_{12}A_{1j} + [m_2\omega_j^2 - (k_{12} + k_{22} + \\ &\quad k_{32})]\,A_{2j} + k_{32}A_{3j} = 0 \\ &k_{13}A_{1j} + k_{23}A_{2j} + [m_3\omega_j^2 - \\ &\quad (k_{13} + k_{23} + k_{33})]A_{3j} = 0 \end{aligned}\right\} \quad (3)$$

For lumped systems, Eqs (3) are

readily set up by observing that the coefficients of each equation (exclusive of the mass-frequency squared product) represent the forces exerted (plus downward, minus upward) on each of the three masses respectively, as a result of a unit displacement of the mass for which the equation is written, all other masses being kept from moving.

This set of equations is indeterminate because the values of the ω and the three A terms are unknown. According to the rules of algebra, if the A terms are to have values other than zero, then the determinant of the coefficients of the A terms must be zero. Thus, the values of ω that make this determinant zero are the correct values to use in Eqs (3) to solve for the A terms. Setting up this determinant and expanding it produces a third degree equation in ω^2, the roots of which yield three values of ω^2. Only the positive square roots have significance, so that the three natural frequencies of the system are obtained.

Since the roots of the frequency equation are all real, no difficulty is experienced in applying usual numerical procedures to the determination of the roots, even for equations of considerably higher order than the third. Even this drudgery may be eliminated to a large degree through the use of an algebraic equation solver (see Hart and Travis, "Mechanical Solution of Algebraic Equations," *Journal of the Franklin Institute*, vol 225, p 63).

On a simultaneous equation machine, Eqs (3) may be solved directly without going through the intermediate steps of expanding the determinant and solving the resulting high degree algebraic equation.

With increasingly complex systems becoming the rule in modern developments, lumping procedures for analysis will increase in scope and will lead to further developments in simultaneous equation solving machines that will make possible the handling of such problems.

Forced Vibration and Impact

If sinusoidal exciting forces of differing phases and amplitudes, but of the same frequency, act on the various masses of the system,

Where

C = the in-phase amplitude component of x

$i = \sqrt{-1}$ indicates a 90 deg phase shift

D = the 90 deg out-of-phase amplitude component of x

F = the resultant exciting force acting on each mass

P = the in-phase amplitude component of F

Q = the 90 deg out-of-phase amplitude component of F

the steady state response may be written as

$$\left.\begin{aligned} x_1 &= (C_1 + iD_1)\sin \omega t \\ x_2 &= (C_2 + iD_2)\sin \omega t \\ x_3 &= (C_3 + iD_3)\sin \omega t \end{aligned}\right\} \quad (4)$$

when the exciting forces are written in the form:

$$\left.\begin{aligned} F_1 &= (P_1 + iQ_1)\sin \omega t \\ F_2 &= (P_2 + iQ_2)\sin \omega t \\ F_3 &= (P_3 + iQ_3)\sin \omega t \end{aligned}\right\} \quad (5)$$

This procedure results in two sets of three simultaneous equations to be solved by the methods already discussed. The equations are:

$$\left.\begin{aligned} &[m_1\omega^2 - (k_{11} + k_{21} + k_{31})]\,C_1 + k_{21}C_2 + k_{31}C_3 = P_1 \\ &k_{12}C_1 + [m_2\omega^2 - (k_{12} + k_{22} + k_{32})]\,C_2 + k_{32}C_3 = P_2 \\ &k_{13}C_1 + k_{23}C_2 + [m_3\omega^2 - (k_{13} + k_{23} + k_{33})]\,C_3 = P_3 \end{aligned}\right\} \quad (6)$$

$$\left.\begin{aligned} &[m_1\omega^2 - (k_{11} + k_{21} + k_{31})]\,D_1 + k_{21}D_2 + k_{31}D_3 = Q_1 \\ &k_{12}D_1 + [m_2\omega^2 - (k_{12} + k_{22} + k_{32})]\,D_2 + k_{32}D_3 = Q_2 \\ &k_{13}D_1 + k_{23}D_2 + [m_3\omega^2 - (k_{13} + k_{23} + k_{33})]\,D_3 = Q_3 \end{aligned}\right\} \quad (7)$$

The values of the C terms are provided by Eqs (6), while Eqs (7) provide those of the D terms, thus yielding both the amplitude and phase of the steady state response of the structure to sinusoidal excitation at any frequency ω.

In impact problems the transient motion of the system is excited. Frequently, by making use of the principle of conservation of momentum, an initial velocity may be determined for each mass of the lumped system. The problem may then be treated as one of free vibration under given initial conditions of velocity and displacement. The equations of this motion are obtained directly from the solution of Eqs (3), using the natural frequencies and mode shapes obtained therefrom. The transient m motion is, then, given by the equations:

$$\left.\begin{aligned} x_1 &= n_1A_{11}\sin(\omega_1 t + \varphi_1) + n_2A_{12}\times \sin(\omega_2 t + \varphi_2) + n_3A_{13}\sin(\omega_3 t + \varphi_3) \\ x_2 &= n_1A_{21}\sin(\omega_1 t + \varphi_1) + n_2A_{22}\times \sin(\omega_2 t + \varphi_2) + n_3A_{23}\sin(\omega_3 t + \varphi_3) \\ x_3 &= n_1A_{31}\sin(\omega_1 t + \varphi_1) + n_2A_{32}\times \sin(\omega_2 t + \varphi_2) + n_3A_{33}\sin(\omega_3 t + \varphi_3) \end{aligned}\right\} \quad (8)$$

where the n terms are numbers that indicate the actual amount of each natural mode present and the ϕ terms indicate the phases.

The problem is to calculate the value of the n and the ϕ terms for the given initial conditions. The value of the A and the ω terms are already known from Eqs (3). Here, again, a double set of simultaneous algebraic equations is to be solved. Note how the simultaneous equation solver is the only tool necessary to obtain transient and steady state responses of linear lumped dynamical systems of any degree of complexity. The equations are:

$$\left.\begin{aligned} X_1 &= n_1A_{11}\sin\varphi_1 + n_2A_{12}\sin\varphi_2 + n_3A_{13}\sin\varphi_3 \\ X_2 &= n_1A_{21}\sin\varphi_1 + n_2A_{22}\sin\varphi_2 + n_3A_{23}\sin\varphi_3 \\ X_3 &= n_1A_{31}\sin\varphi_1 + n_2A_{32}\sin\varphi_2 + n_3A_{33}\sin\varphi_3 \end{aligned}\right\} \quad (9)$$

$$\left.\begin{aligned} \dot{X}_1 &= n_1\omega_1A_{11}\cos\varphi_1 + n_2\omega_2A_{12}\times \cos\varphi_2 + n_3\omega_3A_{13}\cos\varphi_3 \\ \dot{X}_2 &= n_1\omega_1A_{21}\cos\varphi_1 + n_2\omega_2A_{22}\times \cos\varphi_2 + n_3\omega_3A_{23}\cos\varphi_3 \\ \dot{X}_3 &= n_1\omega_1A_{31}\cos\varphi_1 + n_2\omega_2A_{32}\times \cos\varphi_2 + n_3\omega_3A_{33}\cos\varphi_3 \end{aligned}\right\} \quad (10)$$

The X and $\dot{X}$ terms represent the initial displacements and velocities of the three masses in the lumped system. Eqs (9) may be solved for the $n\sin\phi$ terms and Eqs (10) for the $n\cos\phi$ terms, whence the n and the ϕ terms may be determined.

In the event of an impulse of appreciable duration (instead of an instantaneously-acting impact) acting on any one or all three of the masses, Eqs (8) will contain additional terms representing the particular solutions of the equations of motion during the interval of action of the impulse. When the impulse disappears, the equations revert to the forms as given by Eqs (9) and (10). The particular solutions do not introduce any additional unknowns to further complicate the solving process.

Dynamical Analogies

The reduction of a complex system having continuously distributed elasticity and mass into one consisting of concentrated masses and linear springs suggests the possibility of setting up

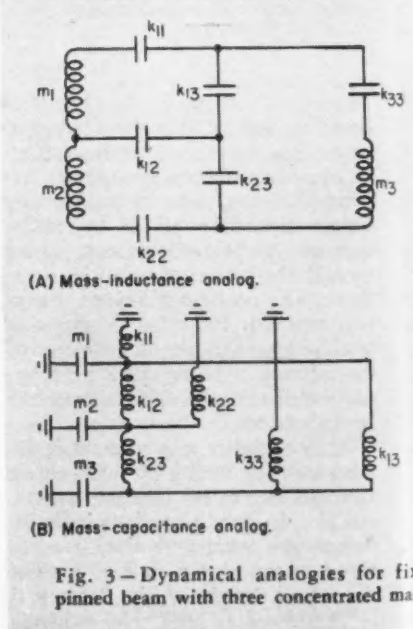


Fig. 3 — Dynamical analogies for fixed-pinned beam with three concentrated masses

a direct physical analogy for the system in the form of an inductance-capacitance circuit. For the system shown in Fig. 2, either the mass-inductance or the mass-capacitance analogy may be used, the circuits for which are shown in Fig. 3. If a problem involving transverse vibrations of a beam (or other structure) is represented by an equivalent system having more than three lumps, the mass-inductance analogy without coupling transformers is no longer possible. An attempt to supply such an analogy usually results in short circuits. The mass-capacitance analogy, however, does not suffer from this defect and may be used for such "nonplanar" systems. In Fig. 4 is shown the mass-capacitance analogy for a system containing six lumps.

Negative Springs

For most problems involving beams, plates, or structures of more general form, it will be found that the equivalent lumped system will require some springs having negative stiffness. When the system is solved digitally or by means of analog simultaneous equation machines, the negative stiffnesses introduce no complications. When it is desired to set up a dynamical analogy, however, negative inductors or negative capacitors are required. For steady state circuits, an inductance will serve as the equivalent of a negative capacitance, and vice versa.

If the frequency of excitation is to be changed, the absolute values of the impedances of a positive inductance and of the capacitive equivalent of a negative inductance change in opposite directions. Hence, in a setup to be operated in the steady state but at a number of different frequencies, variable units must be provided for the elements representing negative stiffnesses. Then, each time the exciting frequency is changed the setting of the negative unit would also be changed to bring its impedance at that frequency to the appropriate value.

As a matter of fact, the system may be operated at constant frequency at all times and the effect of operation at different steady state frequencies obtained by changing the magnitudes of the inductances and the capacitances. These changes would be such as to produce the same impedances as would exist with constant inductance and capacitance at the different frequencies. Such a procedure has certain advantages if the inductance, resistance, or capacitance values in the circuit are frequency-sensitive, although it is cumbersome when many elements are involved. The circuit is not suitable for transient or impact simulation because in such problems many different frequencies are present simultaneously and the circuit can be set up to satisfy only one of them.

Equivalent System for Loaded Cantilever

To demonstrate the application of the method to a specific problem, consider the cantilever beam with three concentrated masses shown in Fig. 5. For this case the influence coefficients are easily calculated at the mass locations, and are found to be

$$\begin{bmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{bmatrix} = \frac{l^3}{6EI} \begin{bmatrix} 2 & 5 & 8 \\ 5 & 16 & 28 \\ 8 & 28 & 54 \end{bmatrix} \qquad (11)$$

Whence the spring stiffnesses are

$$\begin{bmatrix} k_{11} & k_{21} & k_{31} \\ k_{12} & k_{22} & k_{32} \\ k_{13} & k_{23} & k_{33} \end{bmatrix} = \frac{3EI}{15l^3} \begin{bmatrix} 46 & 46 & -12 \\ 46 & -18 & 16 \\ -12 & 16 & 3 \end{bmatrix} \qquad (12)$$

Thus, of the six springs required, two of them must have negative stiffnesses. In Fig. 6 is shown the equivalent electrical circuit.

The preceding development points to a simple means for setting up a lumped system consisting of discrete masses and linear springs, which will be the dynamical equivalent of any distributed system, however complex, for which influence coefficients may be determined. Since the entire development is based on statically-determined influence coefficients, such coefficients may be determined along the three coordinate axes in three-dimensional structures, so that such structures may be reduced to an equivalent single string of masses on linear springs.

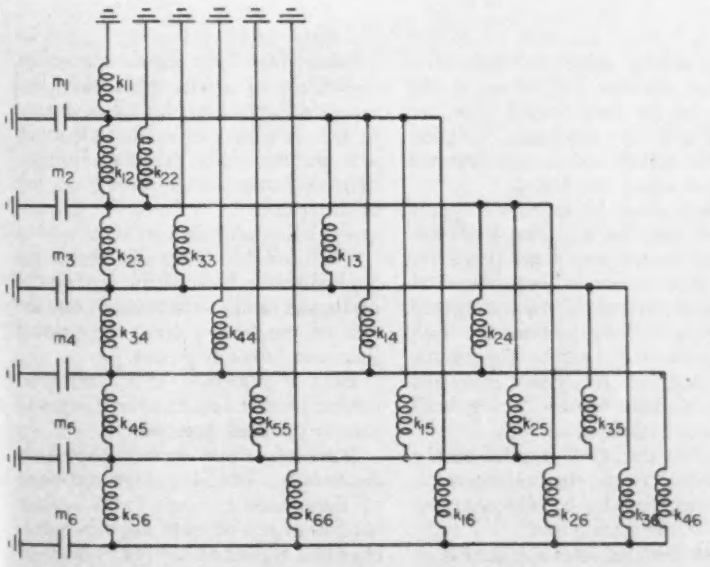


Fig. 4—Mass-capacitance analog for a beam with six concentrated masses.

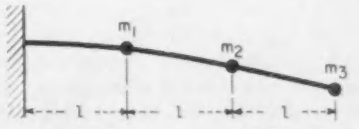


Fig. 5—Cantilever beam with three concentrated masses used in numerical analysis.

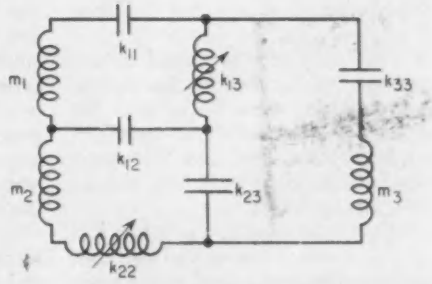
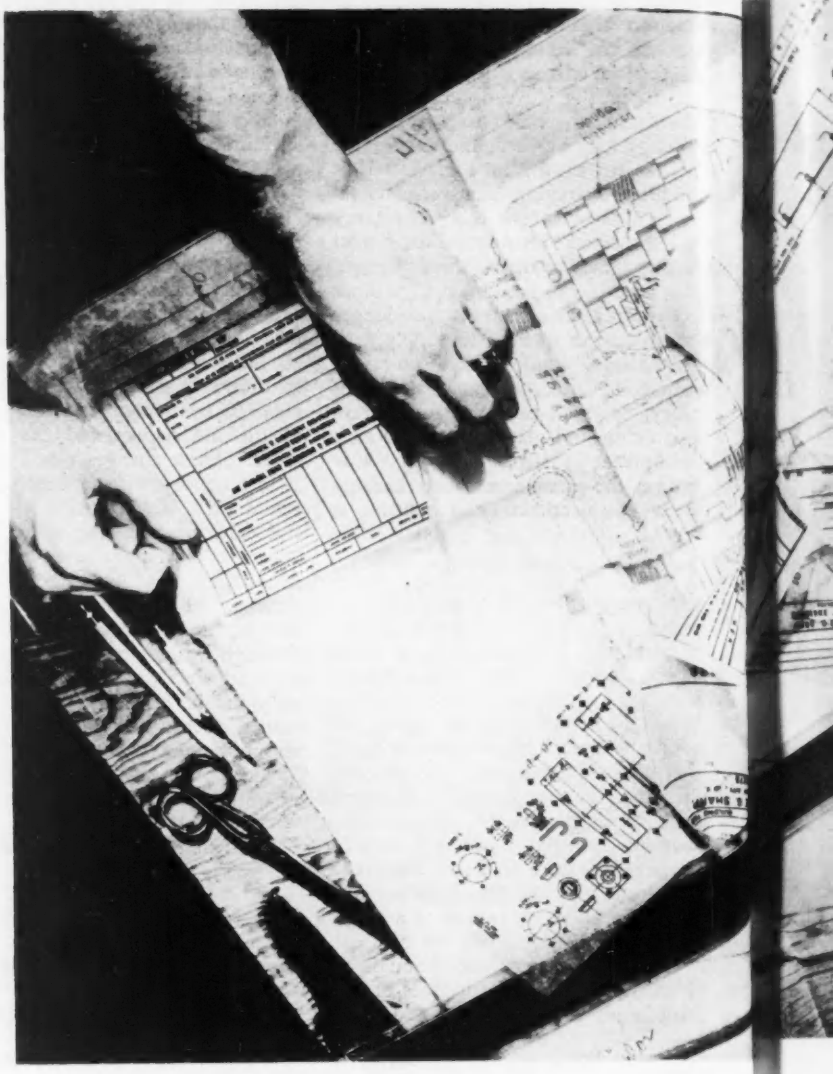


Fig. 6—Mass-inductance analog for cantilever beam with three concentrated masses. The variable inductors represent negative springs.

Reducing Drafting Man-Hours With

Printed Acetate Drawings

STANLEY MAAS
President, Stanpat Engineering Company



PRINTED ACETATE SHEETS can ease the serious bottleneck in the drafting room caused by the shortage of available personnel and the time required to draw complicated equipment. Known as Stanpats, these sheets save drafting room time by reducing the amount of non-creative drawing the draftman does on each tracing.

While originally developed to provide non-smearing title blocks, the acetate sheets are now being used for such applications as bills of materials, standard components and sub-assemblies, and standard notes and instructions, among others.

Stanpats are made of a cellulose acetate sheet with a transparent pressure-sensitive adhesive applied to the front face. Desired material is reproduced by a photo engraving process and printed on the back of the acetate. The adhesive age-hardens after application and has a non-rubber base that prevents bleeding under the heat of a blueprint machine. It locks to the tracing by bonding to the paper or cloth fibers. A wax-paper covering keeps the adhesive clean and prevents premature aging and drying.

It takes about 30 seconds to apply the device to a tracing. The draftsman first removes the wax-paper protective sheet. The acetate is then placed in position on the rear of the tracing and is made to stick by rubbing the wax-paper protective sheet on top of the acetate. Static electricity thus generated makes it adhere to the tracing until the adhesive hardens.

Since the tracing is applied to the rear of the drawing, the draftsman can add information by handlettering on the face of the tracing itself.

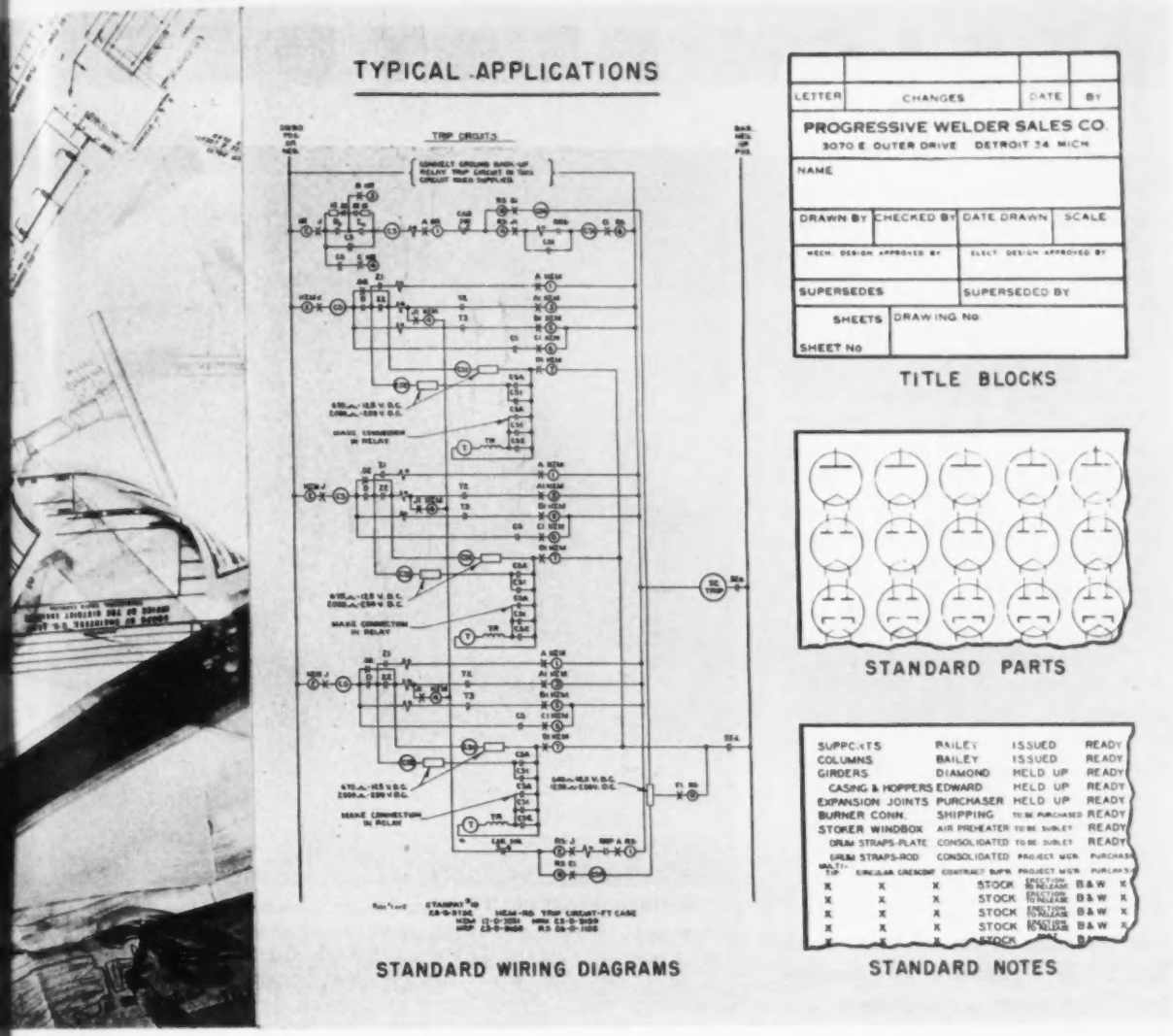
For 30 minutes after application, it is possible to remove the sheet from the drawing if necessary and then reapply it. After that it is permanently bonded. One hour should elapse between the time of application and blueprinting to give the adhesive time to age. A temporary adhesive is available for notes like security classifications that may change during the life of the tracing.

Typical applications include:

Title Blocks. Since the sheets are applied to the back of the tracing the draftsman adds information on the face of the tracing using the printed lines and boxes as guides.

Bills of Materials. An application similar to title blocks saves time and insures standard procedures.

Standard Components and Sub-Assemblies. The biggest potential use of these acetate sheets is to replace hand drawings of parts and sub-assemblies that appear on a large number of tracings. Items like nuts, screws, bolts, electronic tubes, standard motors, pumps, and small wiring diagrams can



be printed up as individual sheets and applied as required. Or a sheet can be printed with several standard parts so that the draftsman can cut out the part he requires and affixes that to the tracing. Detail drawings of parts that are used often can be printed with letters as dimensions. The draftsman tailors each drawing by substituting numerical values for the letters.

Printed wiring sub-assemblies of control components used by one manufacturer resulted in an impressive saving of engineering time. To custom build a control unit, the draftsman places as many of the printed component sub-assemblies on the tracing as required. These are then joined into a complete control unit by a few pencil lines. The company estimates that each sub-assembly wiring diagram formerly took two man-days of drawing.

Since details of the sub-assembly are checked before the acetate drawings are made, the checker need only make sure that the proper sub-assemblies were used and were correctly connected. This procedure reduces chances for error, and time lost making corrections.

Instructions and Notes. Printed instructions prevent the draftsman from wasting time hand-lettering standard information. A recent development enables a typewritten sheet to be used for non-standard notes. To do this a stenographer types these notes on blank acetate forms using a special typewriter ribbon, and the draftsman attaches it to the tracing in the manner previously described. The only difference is that this note is applied to the front of the tracing instead of the rear; thus, the drawing does not have to leave the drawing board when the typed special note is added. The special ribbon does not limit the use of the typewriter since it can also be used for regular correspondence.

Symbols and Classification. Terms such as "For Estimate Only," "For Experimental Use Only," and "Top Secret," that may change during the life of the tracing are printed on acetate sheets which have a temporary adhesive. These can be removed easily and a new classification added.

Repairing Tracings. On torn tracings, strips of blank acetate make invisible repairs that will not reproduce in blueprinting. They have an advantage over other transparent tapes and paraffin materials in that they require no heat for application and heat from the blueprint machine does not affect the bond or the patch.

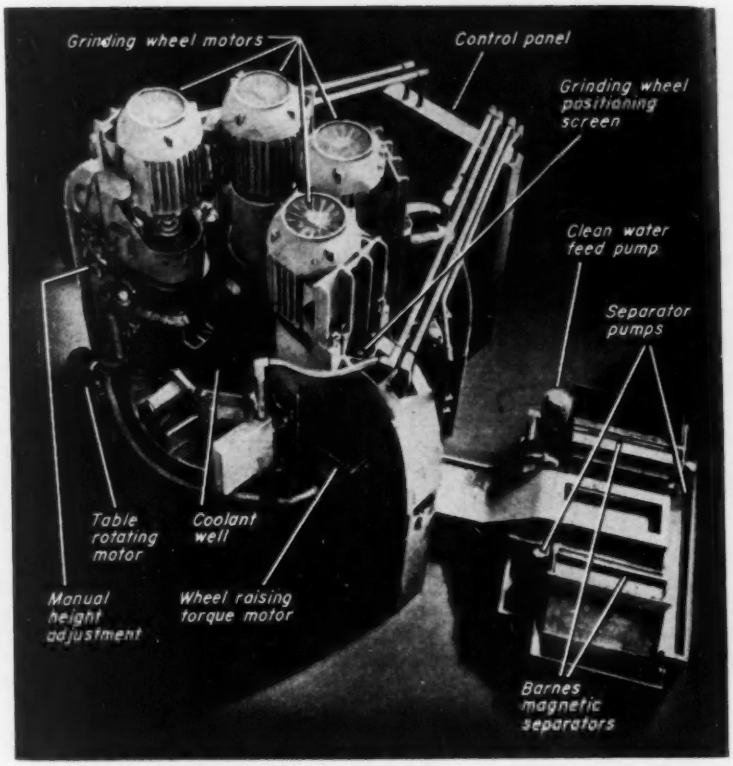
Costs of Stanpats depend on the quantity ordered at one time and the size. On the average, this ranges from less than one cent to a couple of cents a piece.

Time Delay Keeps Coolant Pumps

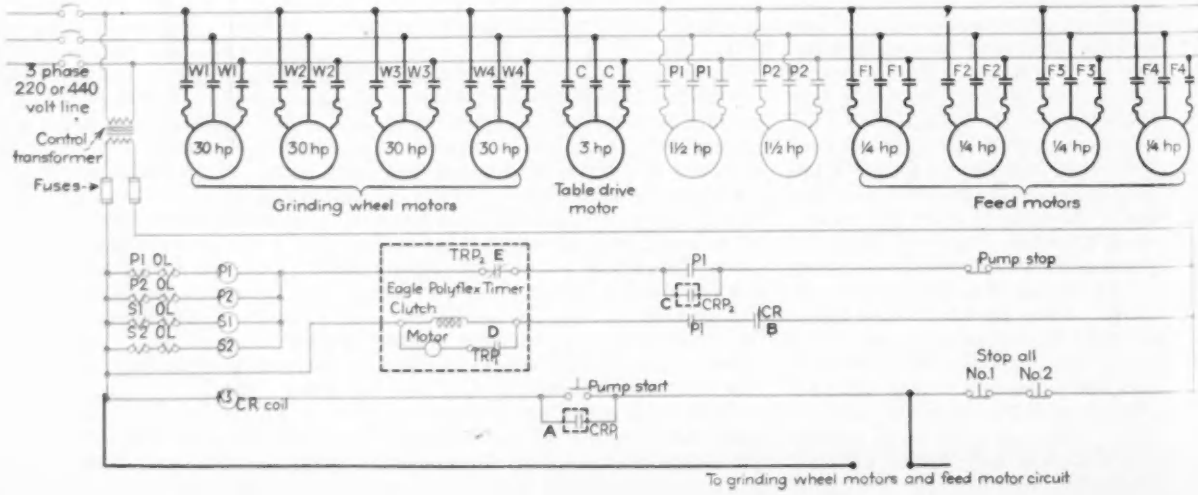
In the new vertical four spindle surface grinder designed by the Blanchard Machine Co., Cambridge, Mass., a time delay system has been used that keeps the coolant water circulating for a predetermined period of time after the grinder has been shut down. When the grinder stop-all button is pressed, a two-pole control relay re-routes the pump electrical circuit through a motor-operated Eagle timer and starts it in operation. After the preset delay has passed (adjustable from 0 to 10 min.) timer opens pump circuit and pumps stop.

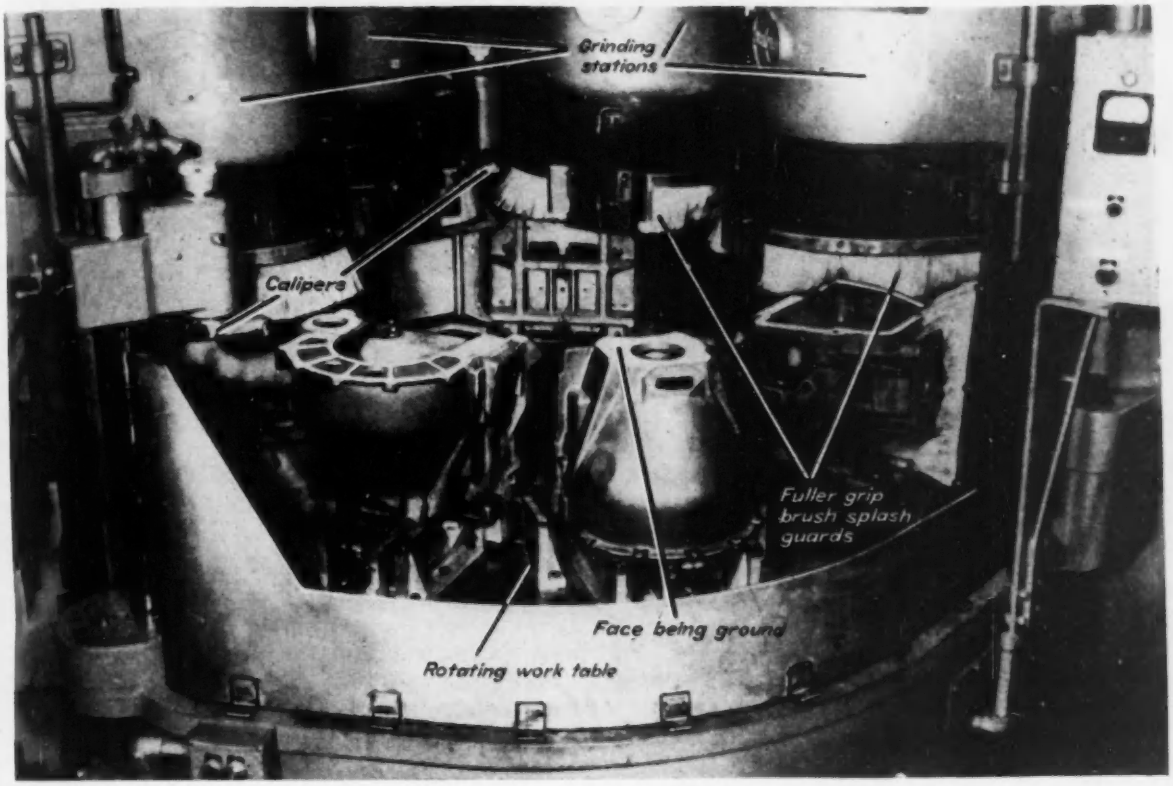
Grinder is a five station rotating table (four grinding stations and one loading and unloading station) with four 22 in. segment wheels mounted on vertical spindles. As the table turns, it carries work from one grinding wheel to the next, each wheel removing a fixed amount of stock.

As the work passes from each wheel, it moves under the pointer of a height-sensitive caliper. If the pointer is moved by the ground work, the caliper closes the feed motor circuit of the wheel just used and that wheel is lowered. This feed can be regulated to keep finished part limits as low as 0.0005 inch.



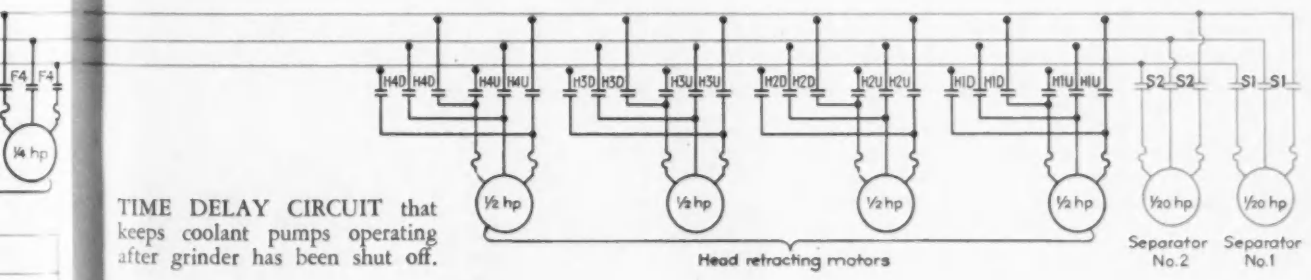
FOUR SPINDLE GRINDER as seen from above. Coolant water cleaning tank at right is connected to the main base by rectangular channel. Two small pumps circulate the dirty water through magnetic separators and the feed pump lifts clean water from the front trough and sends it back to the grinding wheels. Relays keep water running after grinder is shut down.





FIBER BRUSHES are used on the splash guards that keep the coolant from being slung away from the vicinity of the grinding wheel. The brush bristles simply bend to conform to the contour of the work as it passes under the guard. If rubber or metal were used in place of brushes, it would be necessary to cut special splash guards to fit each different shape of piece being ground. Here are shown three clutch housings each being ground on a different face, illustrating the variety of casting contours a given brush type splash guard effectively cover.

Running After Grinder Is Shut Off

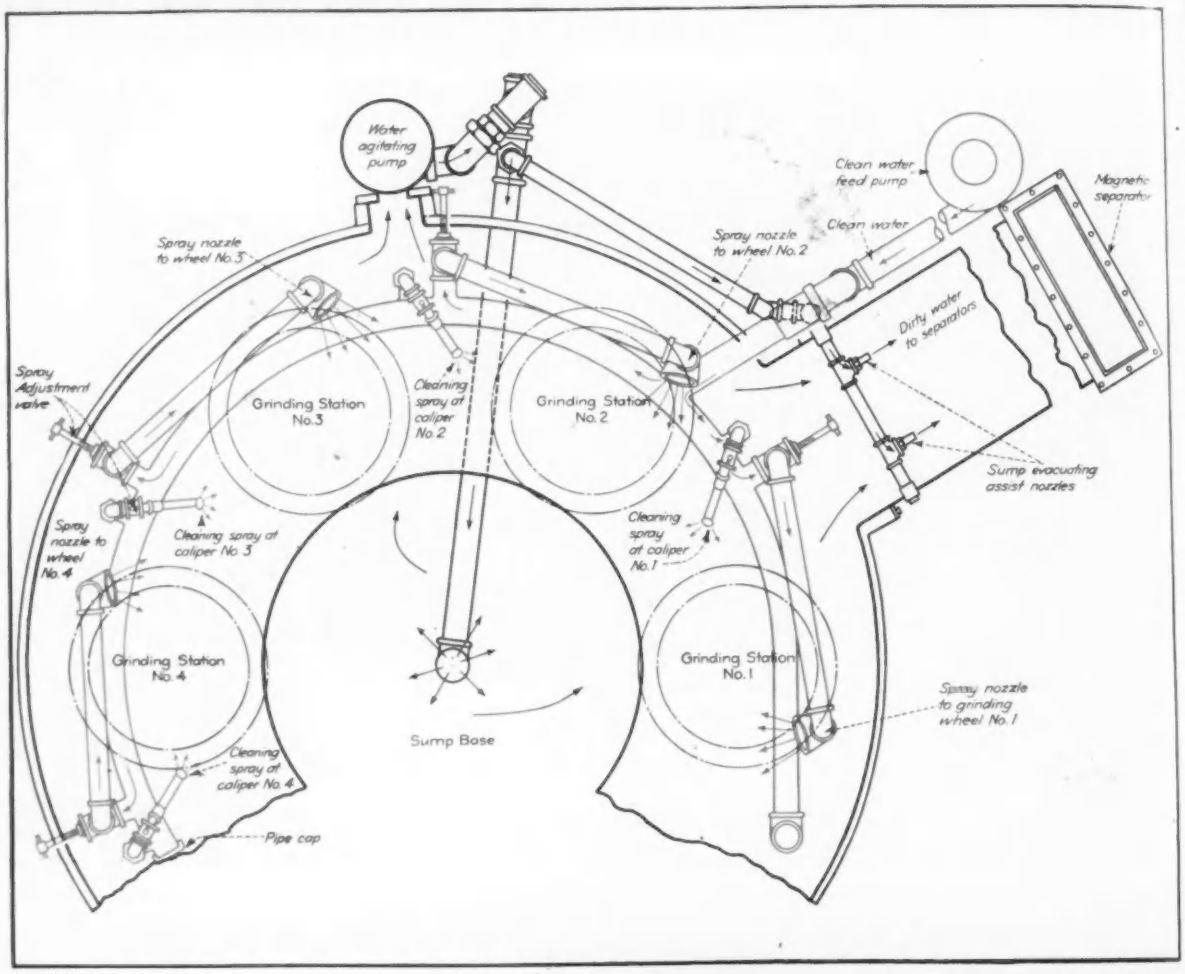


TIME DELAY CIRCUIT that keeps coolant pumps operating after grinder has been shut off.

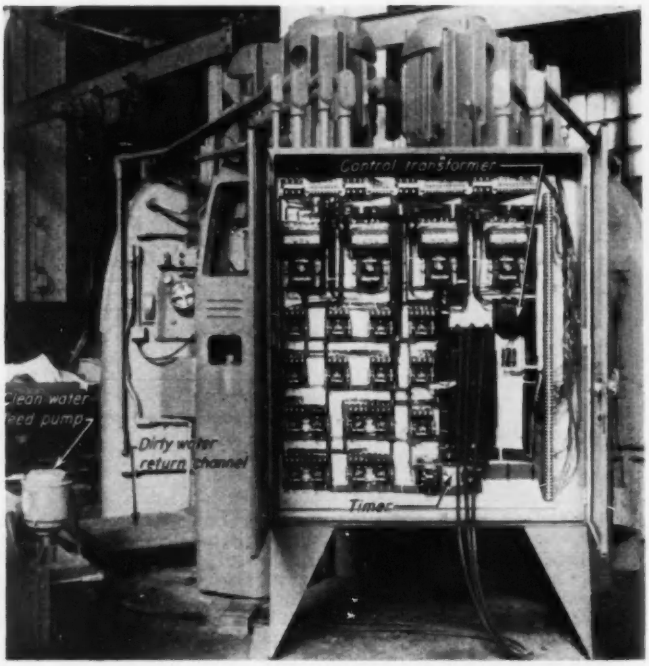
STARTING PUMPS: Normally open pump START button closes circuit to energize coil of 3 pole control relay; contact A closes to maintain circuit after push button is released. Normally closed contact No. B opens. Normally open contact No. C closes. Circuit to coils of pump contactor is closed by control relay contact No. C. A pole of contactor for pump No. 1 parallels the circuit connection with contact C of control relay, which is in series with pump relay coils.

STOPPING PUMPS: Normally closed STOP-ALL button opens circuit to control relay coil. Contacts No. A and C of relay open, but contact No. B closes and circuit through timer, (TR), is complete. Clutch coil closes contact D of time relay, timing motor starts. After the motor rotates set number of turns contact E of time relay is mechanically opened and pump relays are de-energized and pumps stop. Clutch in timer releases time relay contact to timing motor and spring returns timing elements to start.

Time Delay System (continued)



COOLANT WATER CIRCUIT in the grinder frame. Clean water is pumped from the separator tank into a circular manifold, that distributes the coolant through nozzles to the grinding wheels. Each nozzle connection has a flow adjustment valve for maintaining equal distribution. Secondary connections, on the manifold, deliver clean water to the ground surface of the work as it passes from each wheel to insure the face is clean before it contacts the caliper. Loaded coolant drops from the rotating work table into the sump-like base of the grinder frame. The sump is on the same level as the separator tank and the two are connected by a rectangular tunnel. The agitating pump keeps the water moving in the sump and prevents the suspended metal grindings and wheel abrasive from settling out of suspension. The pump also supplies water under pressure to jets in the tunnel to insure flow between sump and separator tank.



CONTROL CABINET houses the relays and timer of entire electric circuit. Orderly arrangement of components and the systematic grouping of relays aid in assembly, identification of components and servicing of the panel. At far right is the terminal strip to which all motor leads are connected.

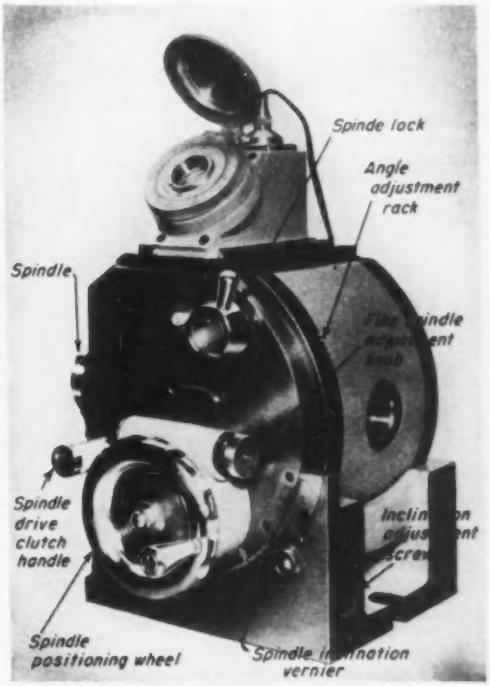
Dividing Head Has Direct Reading Scales

Visual scales on the spindle and housing of this dividing head give direct and accurate readings of spindle position. The design eliminates inaccuracies caused by gear back-lash and oil film thickness in geared dividing heads where spindle position is a function of turns on the hand wheel.

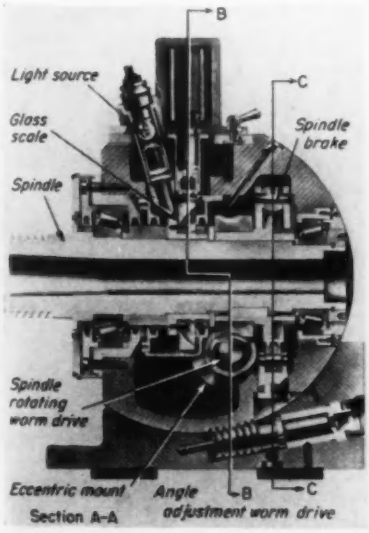
Mounted directly to the spindle is one circular scale marked in degrees. A second scale mounted outside the housing on the work end of the spindle gives approximate rotational location. The first scale, for accurate positioning, is located inside the housing between the two preloaded spindle bearings. It is a glass ring on which degree marks from 0 to 360 are etched with great precision, and so illuminated that their images are projected and magnified, through a prismatic optical system, to a ground glass eye piece on the housing.

To permit changes in the angle of spindle inclination, the spindle assembly and optical system are mounted in a semi-cylindrical housing that rides in a crescent shaped base.

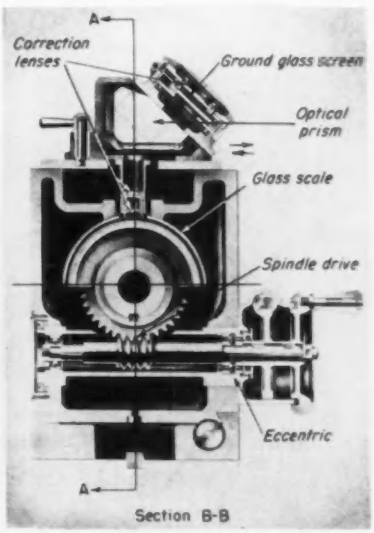
Locks hold the spindle in position after adjustment. A clutch lever is provided to disengage the spindle worm drive. It is made by F. T. Griswold Mfg. Co., Wayne, Pa.



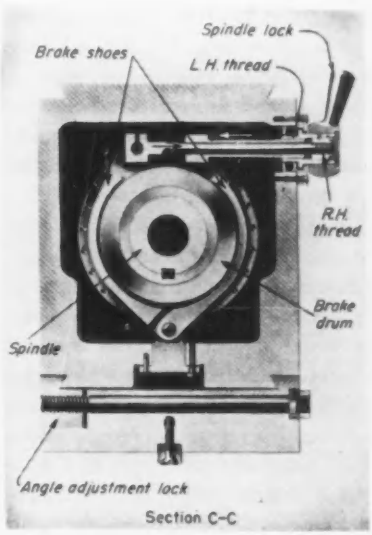
SPINDLE POSITIONING WHEEL is used for rapid and approximate relocation of spindle. Fine adjustment is a helical screw on the wheel shaft. Inclination is adjustable through 95 degrees.



LIGHT to illuminate the etched markings on the spindle mounted glass ring is supplied by the small electric bulb at upper left. A worm screw in the base meshes with teeth on the left dovetail slide of the semi-cylindrical spindle housing to permit spindle inclination adjustments. Notice the eccentric mounting of the spindle worm drive for disengaging spindle.



GROUND GLASS screen in the viewing head registers images of markings on illuminated glass ring. Reflected light passes from the ring through magnification lenses to a trapezoidal prism. The prism is shaped to direct the image to the center of the screen regardless of view head position. The viewing head can be repositioned, to a limited extent, shown by the arrows.



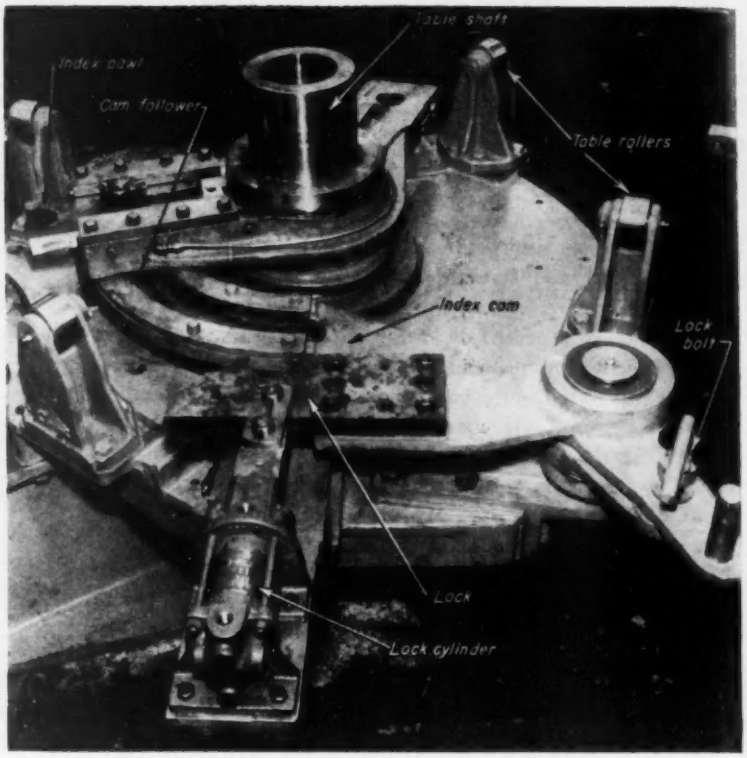
FRICTION LOCKS are provided to firmly hold the spindle after it has been adjusted. Spindle rotation is locked by a double shoe brake. Forces across the brake drum are balanced by using opposed action of right and left hand threads on the compound screen shaft. Spindle inclination lock is a simple screw clamp on the dovetail slide between the base and the body.

Automatic Core Maker Pneumatically Powered

Pneumatic cylinders, controlled by an electric timing circuit, are used to power the actions of an automatic core making machine made by the Osborn Mfg. Co., Cleveland, Ohio. The machine blows prepared sand into conventional type core boxes and delivers the formed cores ready for dipping and baking on dryer plates to appropriate core transporting equipment. It then retrieves the core boxes, cleans and returns them to the blowing station for a repeat performance.

Basically the machine has three sections. (1) A 5-station indexing table that carries the core boxes into position for processing; (2) A core blower that delivers a measured quantity of prepared sand to each core box when the indexing table brings the box into position; (3) A rockover mechanism that inverts the core box to deposit the formed core on a conveyor or other core handling equipment.

Five stations of the indexing table are platens on which the core boxes are secured. These platens are held in open trunnions from which they can be lifted during the blowing and rockover operations. The indexing drive under the table uses two main double acting pneumatic cylinders. The power cylinder turns the table through a gear driven indexing linkage. The index cylinder unlocks the table and engages the indexing linkage when table is to be rotated, or locks the table in position for the blowing and rockover action. The power cylinder then returns the indexing mechanisms for the next action.



PNEUMATIC CYLINDER in foreground positions table lock and moving cam of indexing mechanism. This assembly is under the rotary table which rides on the four ball bearing rollers. The lock and index pawl engage five equally spaced pins on the underside of the table. Table rotation can be reversed by reversing the input air to the lock cylinder.

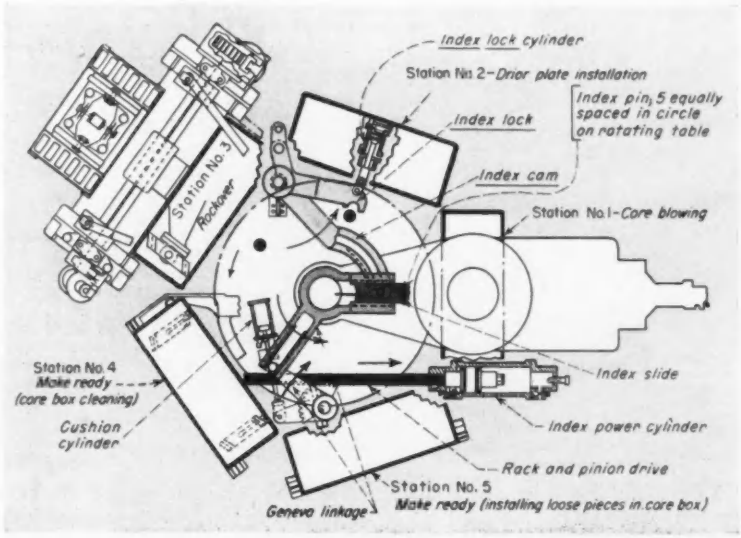
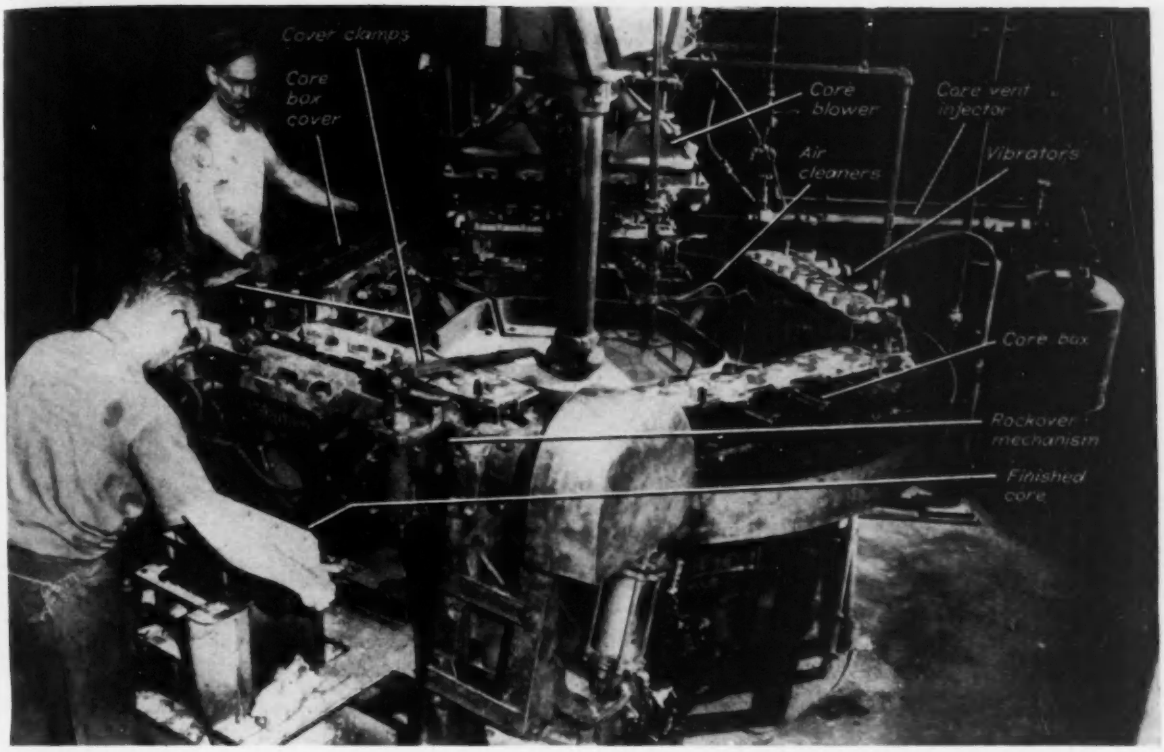
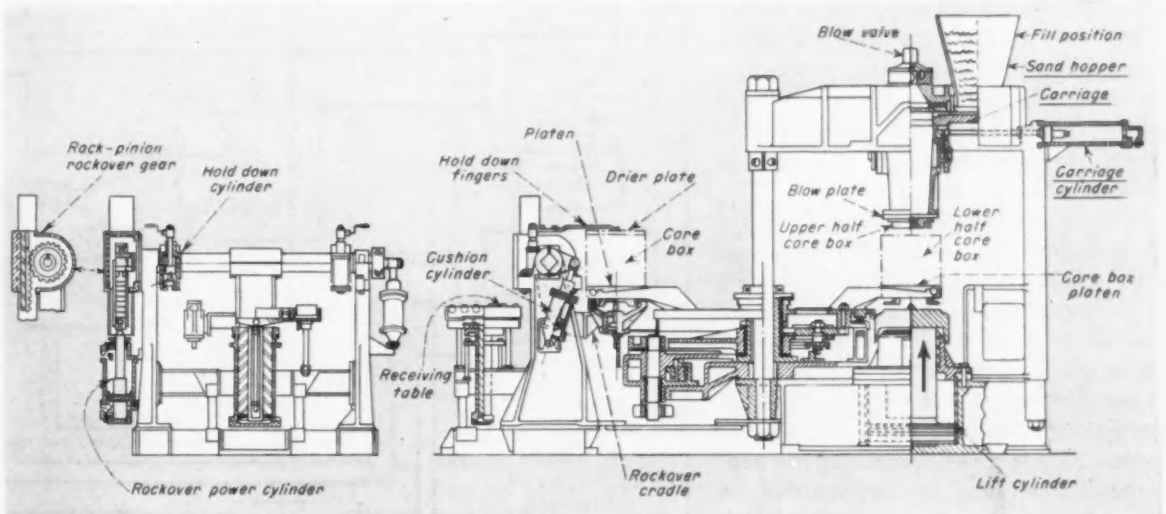

Index lock cylinder
Station No. 2–Drier plate installation
Index pin, 5 equally spaced in circle on rotating table
Index lock
Index cam
Station No. 3 Rockover
Station No. 1–Core blowing
Station No. 4 Make ready (core box cleaning)
Index slide
Cushion cylinder
Index power cylinder
Rack and pinion drive
Station No. 5 Make ready (installing loose pieces in core box)
Geneva linkage

TABLE INDEXING MECHANISM ready to move the core boxes to the next station in the core making cycle. Index lock cylinder withdraws the lock from the index pin in table. The index cam positions the index slide on the index pin of next higher order; power cylinder rotates the table 1/5 turn through rack and pinion combined with Geneva linkage. At end of stroke, air to power and index cylinders is reversed. Lock engages the pin as the slide cam retracts and the Geneva linkage returns to start position.



AUTOMATIC CORE MAKING MACHINE in operation at Buick Motor Car Company making cores for the water jackets in engine cylinder blocks. Core boxes are mounted on index table and moved through five processing stations. As shown, core blower has just retracted after blowing a core in the core box at rear; the rockover mechanism has returned a core box to the table after delivering core to the receiving table and the rotary table is ready to index. An attendant is placing a drier plate on the filled core box ready for delivery. In front are core box cleaning air jets.



CORE BLOWER reservoir is moved from the filling position under hopper to the blowing position over core box, by a pneumatic cylinder. The left cylinder in the base lifts the core box mounting plate out of the trunnion to bring the core box in contact with the blow plate. The blow valve directs air to the reservoir and sand is forced through ports in the blow plate into the core box. When the box is full, air to the blower is shut off, the core box mounting plate is returned to its trunnion, the blower moves back under the hopper for a refill and the table indexes one-fifth turn to bring the next core box into blowing position. At rockover station (left), the platen clamp cylinder and core plate hold down cylinders secure the core box to the cradle. The power cylinder lifts out the plate and upsets it on the table.

Telescriber transceiver c
of a hand writing transmi
tion and an electric pen

The telescriber, an instrume
transmission of hand written
a system of mechanical link
with electrical components
identical motion between th
receiver station and the stylu
mitter; (2) automatically adv
in the receiver a given distan
pletion of each message; (3)
the pen in the receiver; and (
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In the transcriber made by
Corp., New York, the pen act
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When a message has been
operator moves the stylus to a
at the left of the platen and t
his movement to a correspo
over an outlet of the ink w
presses the switch, the wri
de-energized and the pen falls
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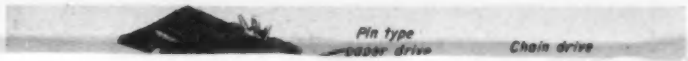
and the ink pump motor start
the paper is advanced to a ne
solenoid closes the motor sw
kept closed by the cam on the

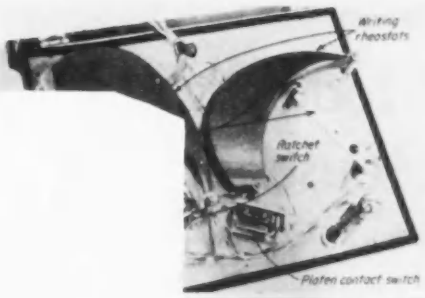
To prevent the pen from
paper except when actually writing, an electro-magnetic pen lifter circuit holds the pen away from the paper until the stylus is pressed to the platen on the transmitter.



BOOK B

TIGHT

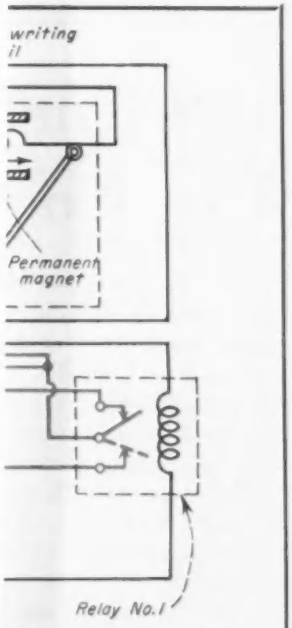
SIMPLIFIED WIRING DIAGRAM of transmitter and receiver shows only writing circuit and paper advance circuits. To close writing circuit (black lines) press and close the ratchet switch. Direct current passes across right and left writing coils. Movements of coils, in a field of a permanent magnet, are induced by changing values of currents at variable rheostats attached to stylus in trans-



BOUND

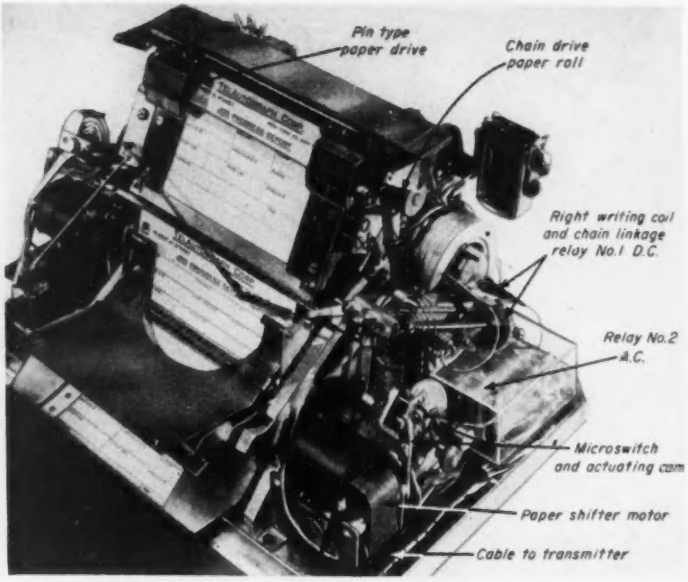
HTLY

ECTION. Mechanical link- resolves movement of stylus on of pivot shafts. Pivot connected to contactor arms ottom view). These arms ltage output of the rheostats on of the stylus.



mitter. When left coil moves from rest position, left lever turns on switch, closes circuit to relay No. 1. Energized relay No. 1 closes a-c circuit to relay No. 2 which from then on will energize itself. When finished writing, to energize paper advance circuit (red circuit) press and open ratchet switch. De-energized relay No. 1 closes circuit to paper shifter solenoid, which ... anically closes motor switch. After motors have started, cam on shaft momentarily opens Micro Switch to de-energize relay No. 2. But notched wheel on paper roll keeps motor switch closed until paper is repositioned and Micro Switch is closed again, ready for next paper advancing operation.

Telescriber transceiver composed of a hand writing transmitter section and an electric pen receiver.


Pin type paper drive
Chain drive paper roll
Right writing coil and chain linkage relay No.1 D.C.
Relay No.2 A.C.
Microswitch and actuating cam
Paper shifter motor
Cable to transmitter

MECHANICAL COMPONENTS on left side of receiver that directs action of electric pen and paper shifter. Pen is shown in rest position at ink well with left writing coil holding contacts of turn on switch open. The solenoid mechanically closes the motor switch before its circuit is opened but the motor switch is kept closed by the cam on the paper roll until paper is fully advanced. The ink pump motor runs simultaneously with the paper advance motor.

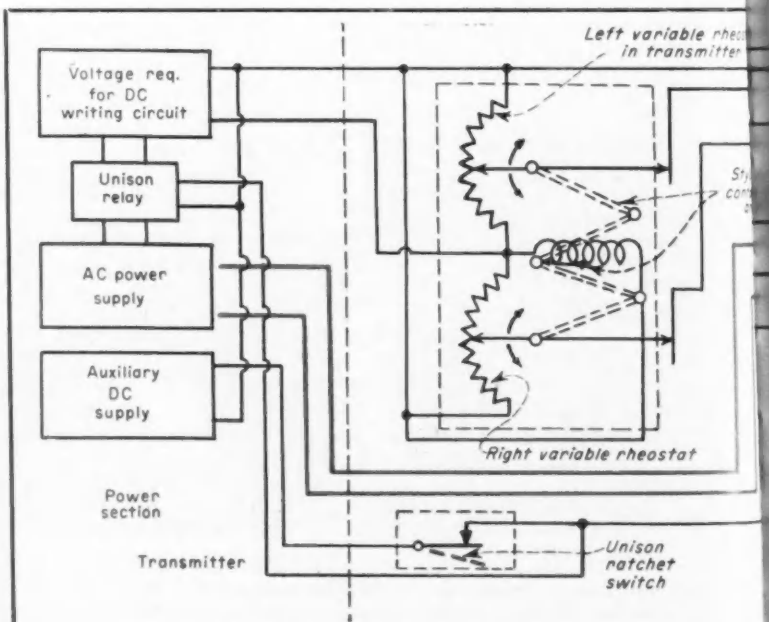
Combined Electro-

The telescriber, an instrument for electrical transmission of hand written messages uses a system of mechanical linkages combined with electrical components to (1) induce identical motion between the pen in the receiver station and the stylus in the transmitter; (2) automatically advance the paper in the receiver a given distance at the completion of each message; (3) provide ink for the pen in the receiver; and (4) prevent the pen from marking the paper except when writing action is desired.

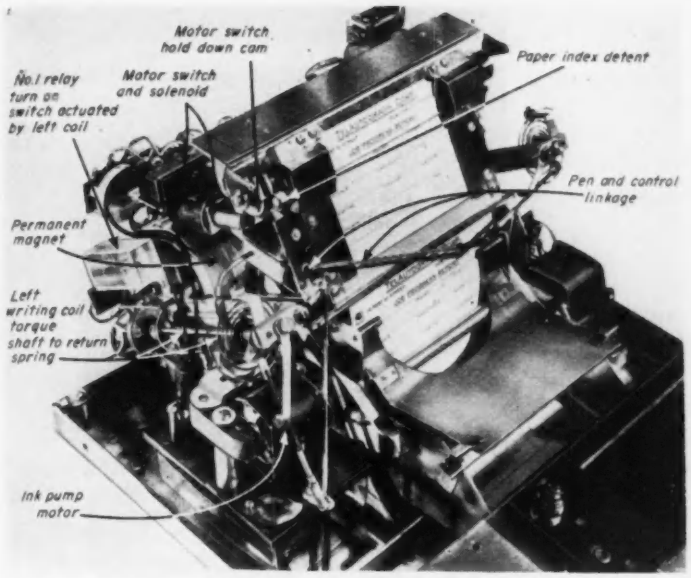
In the transcriber made by TelAutograph Corp., New York, the pen action follows the stylus through the combined action of two coils moving axially in the field of a permanent magnet. They act similar to volt meters, with their pointers connected to the pen, and respond to d-c voltage input as regulated by variable rheostats, connected to the stylus, in the transmitter.

When a message has been completed, the operator moves the stylus to a ratchet switch at the left of the platen and the pen follows his movement to a corresponding position over an outlet of the ink well. When he presses the switch, the writing circuit is de-energized and the pen falls into the opening. Simultaneously, the paper shifter motor and the ink pump motor start, and run until the paper is advanced to a new position. A solenoid closes the motor switch which is kept closed by the cam on the paper roll.

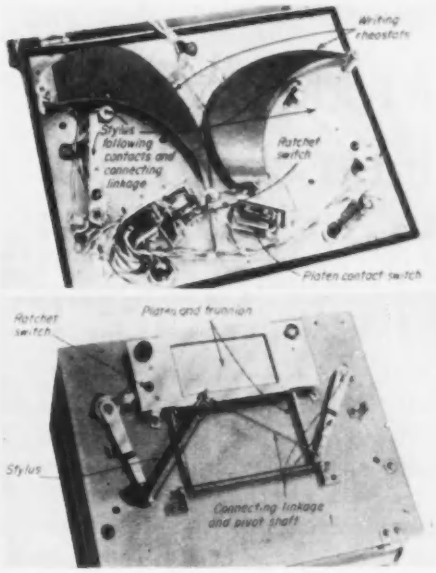
To prevent the pen from marking the paper except when actually writing, an electro-magnetic pen lifter circuit holds the pen away from the paper until the stylus is pressed to the platen on the transmitter.



SIMPLIFIED WIRING DIAGRAM of transmitter and receiver shows only writing circuit and paper advance circuits. To close writing circuit (black lines) press and close the ratchet switch. Direct current passes across right and left writing coils. Movements of coils, in a field of a permanent magnet, are induced by changing values of currents at variable rheostats attached to stylus in trans-

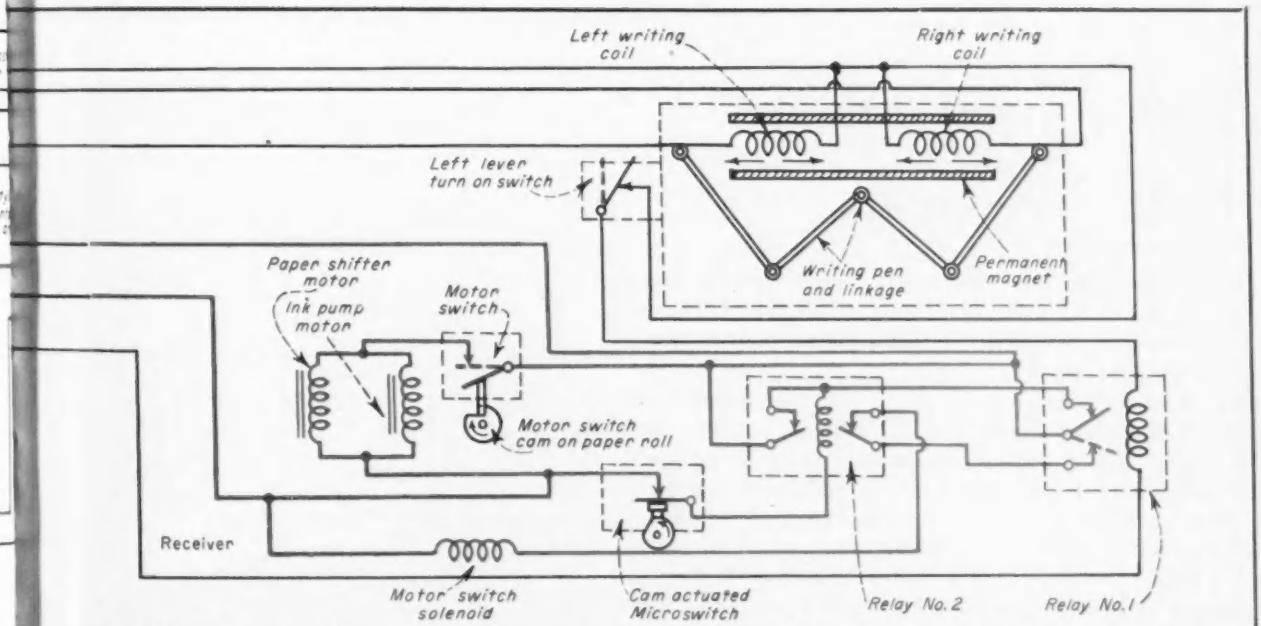

Motor switch hold down cam
Paper index detent
No.1 relay turn on switch actuated by left coil
Motor switch and solenoid
Pen and control linkage
Permanent magnet
Left writing coil torque shaft to return spring
Ink pump motor

RIGHT SIDE VIEW of receiver shows flat on actuating cam that momentarily opens micro-switch to de-energize relay No. 2 and motor switch solenoid. Cam action (left view) keeps motor switch closed until paper is fully advanced and rotation continues long enough to reclose Micro Switch ready for the next paper advance operation. Here can be seen the ball-link chain that transmits lateral motion of the right writing coil to rotary motion of the pen linkage pivot shaft.



TRANSMITTER SECTION. Mechanical linkage (top view) that resolves movement of stylus into rotating motion of pivot shafts. Pivot shafts are directly connected to contactor arms under the cover (bottom view). These arms regulate the d-c voltage output of the rheostats according to position of the stylus.

Mechanical Action of Telescriber



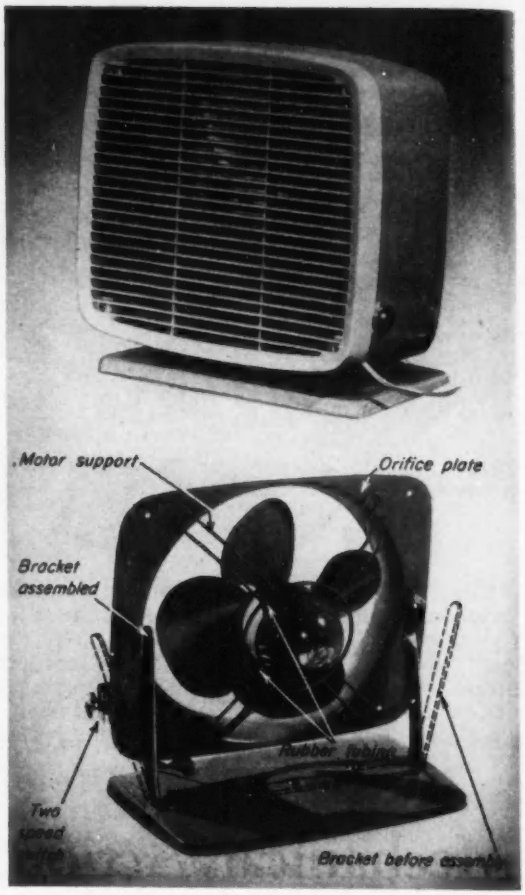
mitter. When left coil moves from rest position, left lever turns on switch, closes circuit to relay No. 1. Energized relay No. 1 closes a-c circuit to relay No. 2 which from then on will energize itself. When finished writing, to energize paper advance circuit (red circuit) press and open ratchet switch. De-energized relay No. 1 closes circuit to paper shifter solenoid, which mechanically closes motor switch. After motors have started, cam on shaft momentarily opens Micro Switch to de-energize relay No. 2. But notched wheel on paper roll keeps motor switch closed until paper is repositioned and Micro Switch is closed again, ready for next paper advancing operation.

Modernized Household Fan Has Safety Grille, Single Motor Bearing

In preparation for designing their new all-purpose fan, the Small Appliance Division of General Electric Co., Bridgeport, Conn. conducted a survey program to determine how large the openings for the protective grille should be to afford maximum safety. After determining the average length to thickness ratio of human fingers most prone to injury in household fans, they adopted a grille design of horizontal bars $\frac{3}{8}$ in. apart and set $1\frac{1}{2}$ in. from the fan blades.

To compensate for the head loss through this grille, the fan is set in a venturi-type orifice that speeds the air through the fan and keeps performance comparable to that of conventional design.

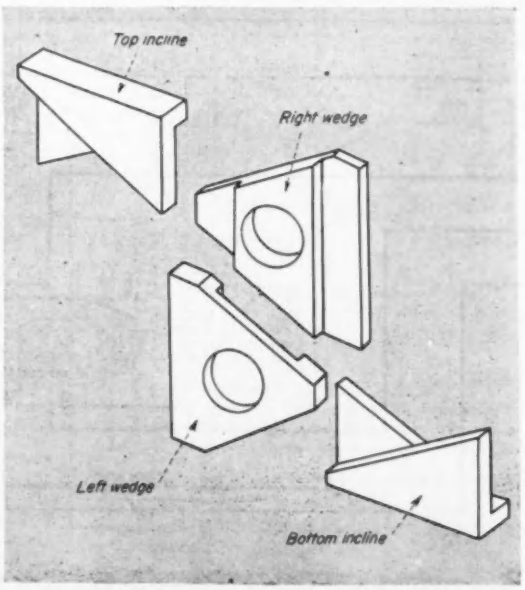
The orifice plate serves as a main mounting frame for the fan assembly. The brackets on which the motor is held, are welded to the orifice. The plate also carries the weight of the fan and the housing at two welded on trunnions located at the center of gravity for balance.



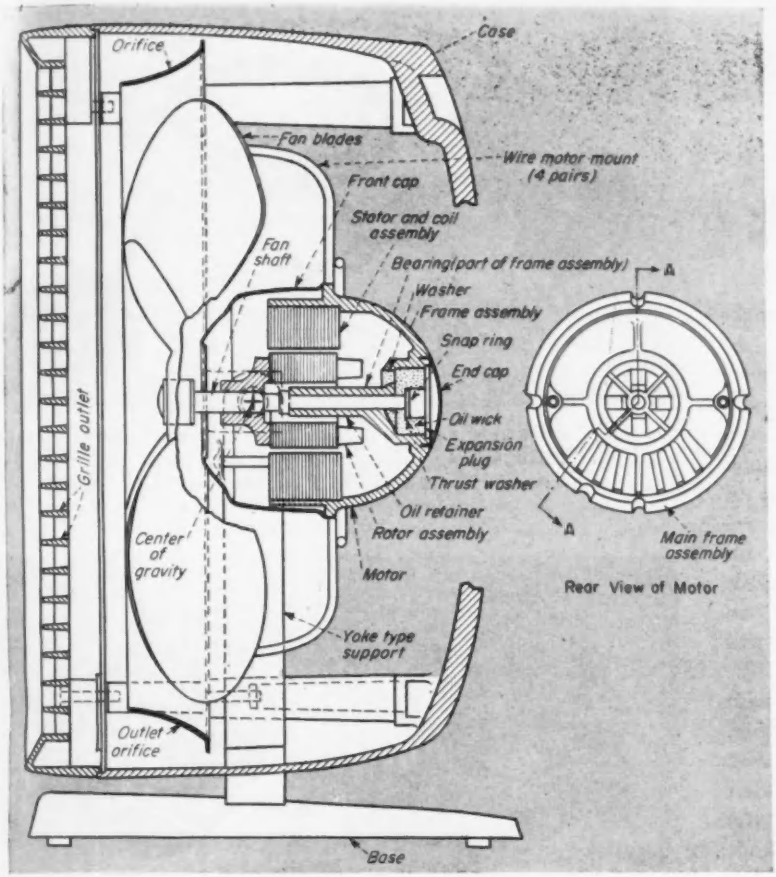
Differential Drive Uses No Gears

Here is a gearless differential, one of several designs developed in Europe during and since World War II. The Germans used this type of device in the power train in some of their armored vehicles. Because of the relative ease and accuracy with which the parts can be made, as compared with the bevel gears of conventional differentials, intensive study has been made of gearless differentials that can be applied to analog computers. They are used for mathematical elements where rotational value of an output shaft depends on the relative rotational values of two input shafts.

The basic idea in all the designs is to replace the precision cut gear commonly used, with crank shafts and other Kinematic equivalent parts that are easy to make. This one uses a system of inclined planes and wedges to distribute rotational quantities to the three rotating members, in a fixed relationship and according to the mechanical requirements of each.

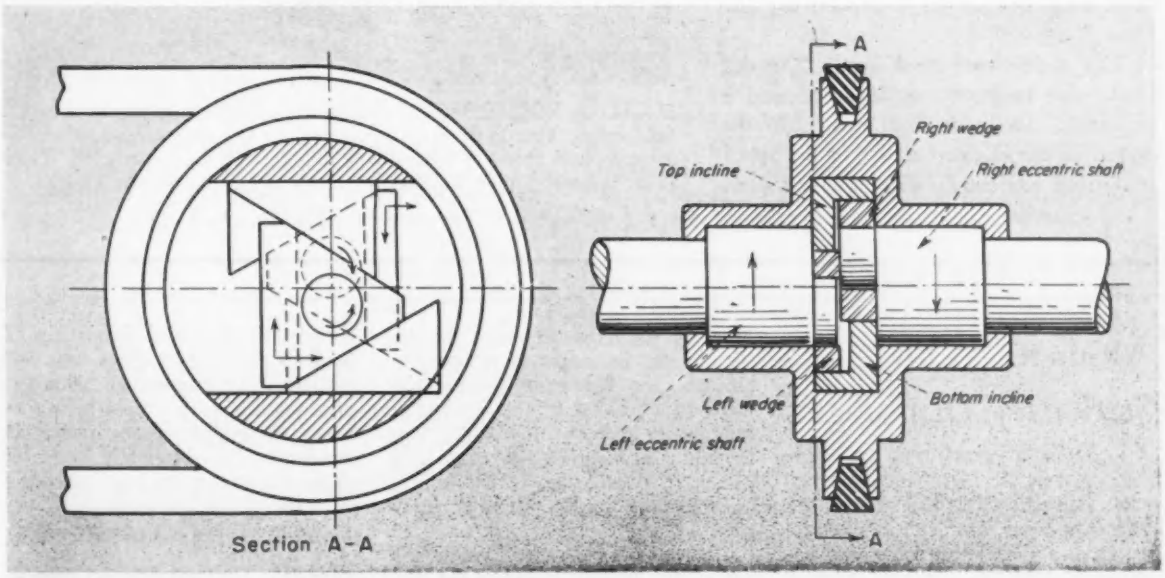


TONGUE AND GROOVE between wedges keep them in phase horizontally but permit vertical movement. Inclines keep wedges out of phase vertically.



PLASTIC HOUSING of all purpose fan is styled in two-tone frost-gray. It measures 14½ in. wide, 14 in. high, 9 in. deep and weighs 11½ lb. The fan operates on 60 cycle 110-120 v current, will deliver 1,050 cfm at 1,300 fpm velocity. The push button switch provides two fan speeds and shutoff. Notice the horizontal bars of the front grille. Spacing has been set to prevent fingers from reaching the whirling fan blades. Dotted lines on the photo of fan-base assembly show the position to the mounting bracket before the fan assembly is mounted. Spring tension forces the bearing ends of the bracket against the trunnions and provides the friction for holding the fan in a tilted position. To insulate the fan housing from motor vibration the rear cap clamps around short sections of rubber tubing on wire.

MOTOR AND FAN SHAFT bearing mount is an integral part of the die cast aluminum housing. It is a cantilever tube that extends inside the rotor. Thrust washers on each end of the shaft prevent lateral motion of the fan and lubrication is supplied by the felt packing. Holding brackets are mounted on the orifice plate at the center of gravity to provide balance for the fan at any degree of tilt.



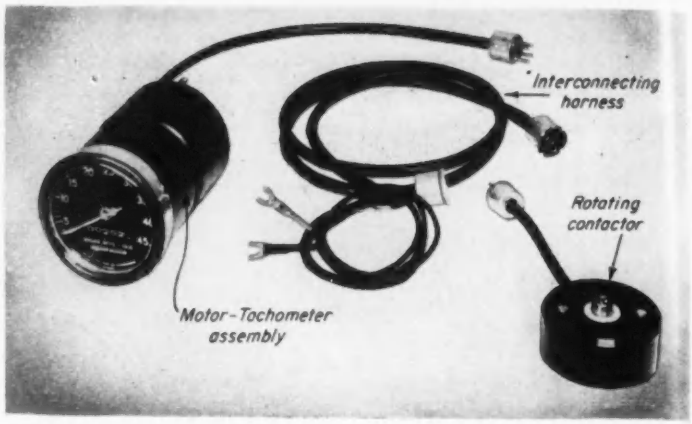
ARROWS ON CROSS-SECTION show action of parts as shafts rotate with the cage held stationary. An eccentric on each shaft fits in a wedge. By virtue of their tongue-groove slide union, both wedges move together. The compound incline blocks are displaced in the cage and direct the sliding action between the wedges and prevent dead spots.

Tachometer Motor With Magnetic Lock

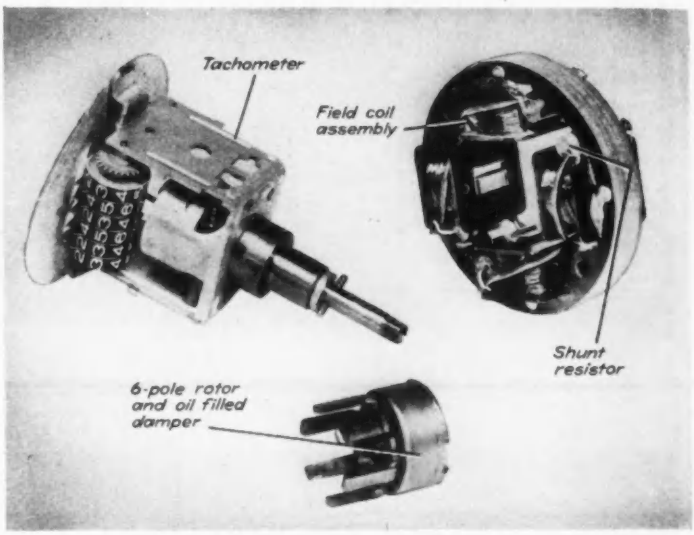
A special motor was developed for the tachometer drive of this kit, designed by Stewart-Warner Corporation to provide truck operators with accurate readings of engine speed regardless of adverse operating conditions. The speed of the motor is positively regulated by an interrupted d-c circuit the frequency of which is controlled by a rotary switch designed for easy installation in the engine distributer. Extreme changes in temperature, low battery voltage or faulty engine ignition will not affect its accuracy.

The motor has a four pole field with diametrically opposite coils wired together, and a six-bladed soft iron rotor connected directly to the tachometer shaft. Rotation is induced by alternately energizing the two opposing pairs of field coils. The sending switch consists of a phenolic rotor and three electro-graphitic brushes, that contact a copper sleeve insert molded into the rotor. These elements are held in a housing that nests between the distributer cap and base.

The tachometer head has a 270 deg scale that indicates engine speed and a totalizer. Its input shaft turns 1/6 the speed of the engine because of the speed reduction attained in the impulse motor.



COMPLETE electrically driven tachometer consists of a motor-tachometer assembly, interconnecting harness with polarized plugs and a sending switch that can easily be adapted to a conventional truck engine.

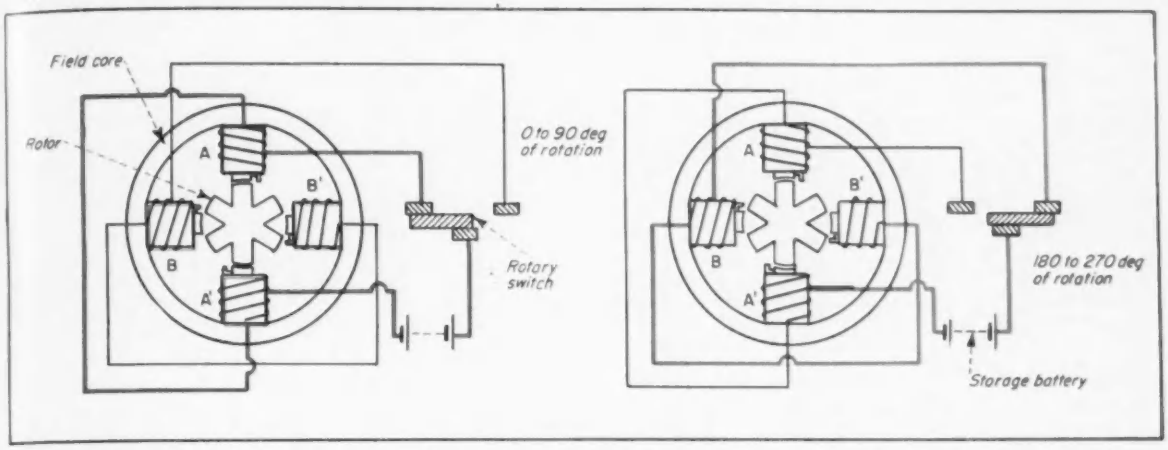


SIX-POLE ROTOR keyed on tachometer shaft is surrounded by four field coils. The oil-filled cylinder on the rotor dampens impulses from the coils and produces a consistant rotation for the tachometer. Notice shunt resistor to short high inductive voltage and minimize arcing.

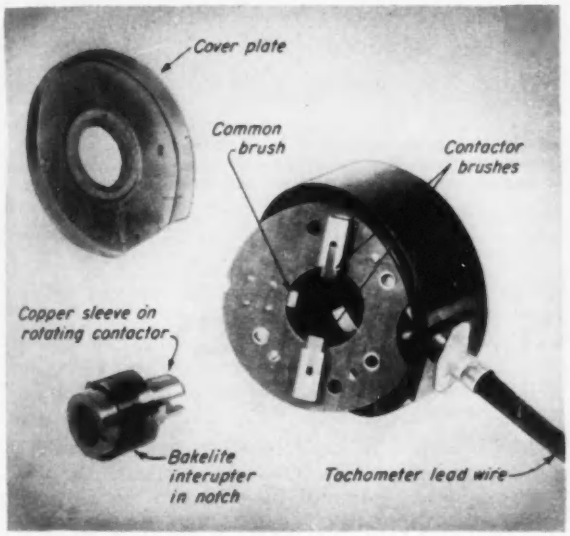
Altimeter With Stationary Diaphragm

AN AIRPLANE ALTIMETER has been developed by Jacobs Instrument Company, Bethesda, Md., that reduces the danger of meter inaccuracies caused by hysteresis and creep of the metal diaphragms used in standard aneroid altimeters. The new design uses a metallic diaphragm much the same as conventional altimeters. But instead of using the movement of a metallic diaphragm, in response to pressure changes, for indicating altitude this meter measures the balancing pressure required to keep the diaphragm from moving. By keeping the diaphragm stationary, peculiarities in its resilient qualities do not affect meter performance.

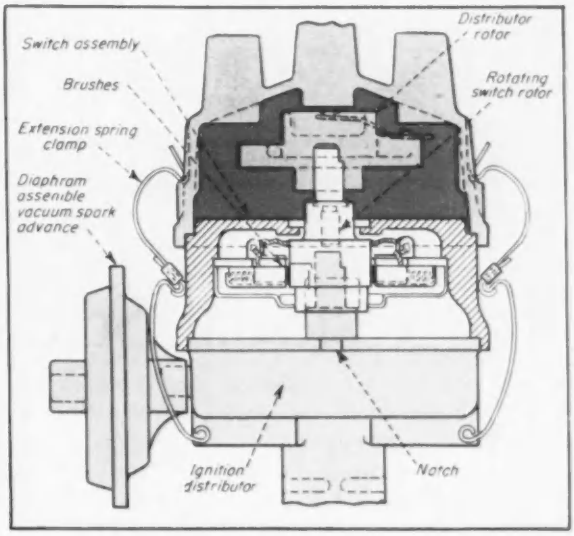
The pressure balancing element is a piston that extends through the diaphragm into a sealed air chamber behind it. As altitude is changed, the piston changes the volume of the sealed chamber and keeps the air pressure balanced across the diaphragm. The trapped air behind the diaphragm acts as a fluid spring and resists movement of the piston and the diaphragm. Normally, both sides of the diaphragm are kept exposed to the existing air pressure. When a change in altitude is to be measured, a valve is closed to seal the air in the chamber. This removes the need for manual readjustment of the altimeter to conform with changes in atmospheric condition.



ACTUAL SWITCHING CYCLE: during first 90 deg of switch rotation, coils *A* and *A*[1] are energized; second 90 degrees all coils are energized; third 90 deg, coils B and B[1] are energized; last 90 degs, all coils are energized. At no time are all the coils de-energized. This transfer of magnetic attraction produces the interlocked action.



COMPONENT PARTS of the rotary sending switch. A copper sleeve insert, notched as shown, is molded into the mica filled phenolic rotor. Bottom half contacts the common brush, and the notch delivers interrupted circuits.



ROTARY SWITCH ASSEMBLY nests between the distributor cap and the base without altering engine timing. The friction of the brushes riding on the ground rotor is not sufficient to upset the automatic spark advance.

Plastic Blowers for Electric Motors

The present critical materials shortage has led to the adoption of plastic for many machine parts where the new material has proven itself better suited to the application than the accepted metal it replaced. One example of this trend in progressive expediency is found in the fan cooled "Lifeline" motors made by Westinghouse Electric Corp. in Buffalo, N. Y.

The blowers for these small, totally enclosed a-c motors are now being made of polyester resin, reinforced with glass fibers. The material previously used was die cast aluminum or bronze. The new blowers are capable of more universal application because they have greater resistance to corrosion and are lighter in weight.

Glass fiber is used as reinforcing rather than organic fiber because it has greater resistance to chemical attack and gives the blower greater strength. The decrease in weight of the blower brought about from making it of plastic is about one-third of its original weight in metal. Although this decrease of weight is actually small, it is significant in reducing the inertia effect of the motor where frequent and rapid reversals are required.

The new blowers are now being used on lifeline motors in ratings of 5 and 7½ hp at 1,750 rpm (NEMA frame 254 and 284). Later they will be used on other motor sizes in this line.

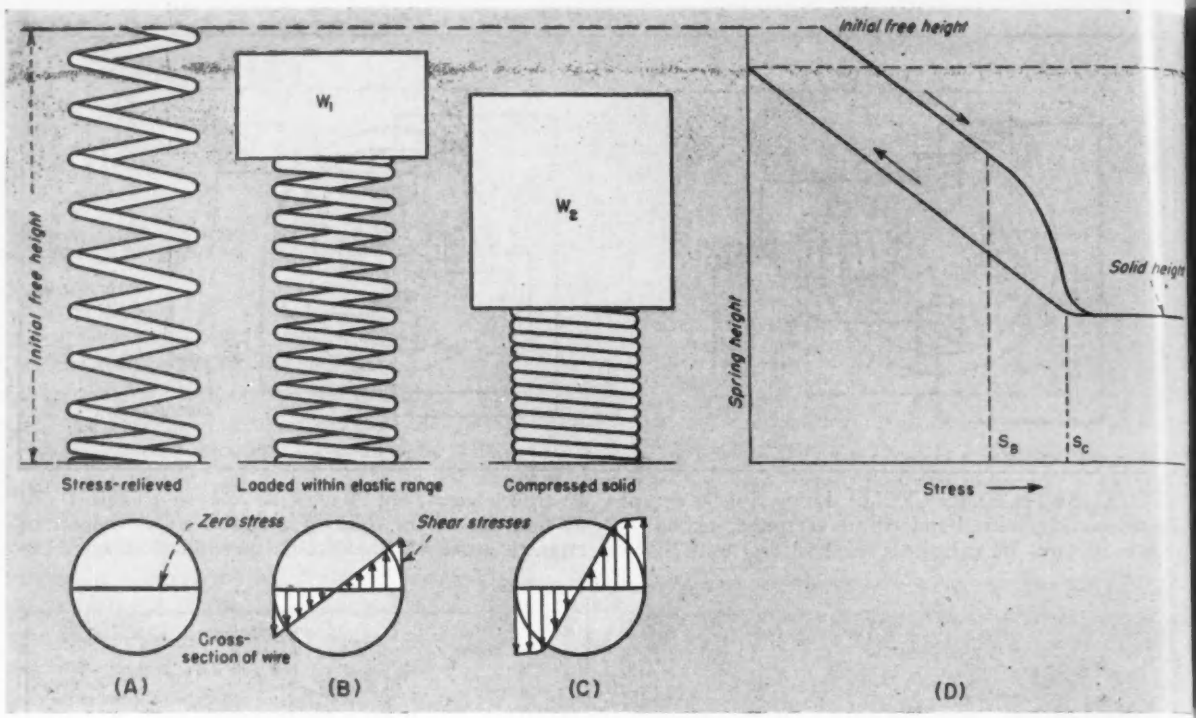


Fig. 1—Step-by-step account of how residual stresses are controlled in compression springs to reduce maximum value of stress resulting from a given load. Stress-relieving (A) removes stresses caused by coiling and other cold working operations. These are objectionable since they are impossible to evaluate. Load W_1 will impose shear stresses (B) on the stress relieved spring.

Residual Stresses in Springs

O. G. MEYERS
Hunter Spring Company

RESIDUAL STRESSES are an advantage in loaded members if they oppose the working stresses, but are a disadvantage if they add to the working stresses. In the case of springs, longer life and increases, up to 30 percent, in the maximum allowable working stress can be obtained if residual stresses are controlled in accordance with this general rule. To effect this control, two tools are used; stress-relief and cold-setting.

Stress relief reduces or removes the residual stresses that are produced during the coiling and other cold-working operations. It usually consists of heating the entire spring to a specified temperature and keeping it at that temperature for a predetermined time. Typical values of temperature now being used are: 250 F for phosphor-bronze; 475 F for music wire, oil tempered hard drawn; 750 F for 18-8 stainless steel. The soaking time varies from one half to one hour depending on the wire size and load values.

A stress-relieved compression spring is shown in Fig. 1 (A). An axial load W_1 placed upon such a spring produces torsional shear stresses as shown in (B). These stresses are less than the proportional limit of the material and will be removed if the load is released.

In (C), a heavier load, W_2, deflects the spring to solid compression and induces shear stresses above the proportional limit. These will not be removed completely when the load is released, but some condition as illustrated by (E) will remain. This deliberate over stressing is called cold-setting; the spring has set to a shorter length than it originally had.

When load W_1 is again applied, (F), the stresses are more evenly distributed over the wire diameter than when the same load was applied to a stress-free spring. The stress on the outside surface, which previously was the maximum value, has been reduced considerably. The result is similar to that of increasing the proportional limit of the spring material as shown by the stress-deflection curve in Fig. 1 (D). Cold-setting increases the proportional limit from S_b to S_c. The curves in Fig. 2 show the maximum values of S_c that can be obtained with different spring metals.

Although residual stresses affect all types of springs, it is not always desirable to use stress relief or cold-setting. The following paragraphs indicate, in general, the procedure followed by spring manufacturers. Within each category, however, the specific design and application requirements must determine what treatment is necessary or practical.

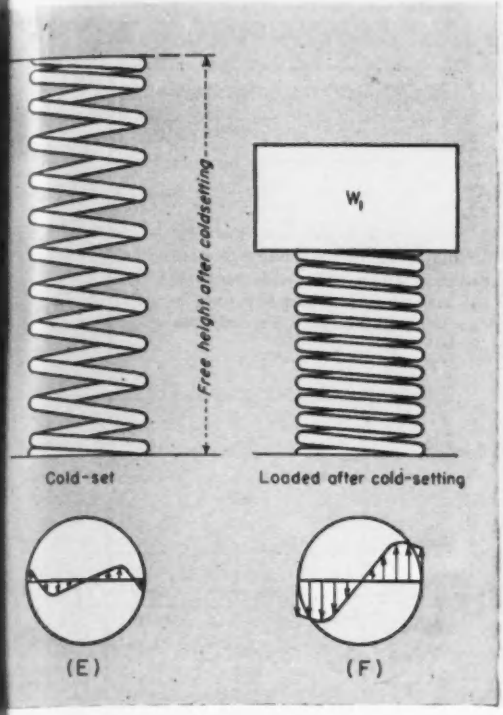
Compression Springs

Compression springs are always stress-relieved to remove residual bending stresses produced by the coiling operation. After stress relief, they are classified as one of the following:

(1) No cold-setting, can be compressed solid

(2) Cold-setting, then can be compressed solid

(3) No cold-setting, cannot be compressed solid without setting.



After cold-setting, (C) and (E), however, the same load will result in stress pattern shown in (F). Letters on curve (D) refer to the sketches.

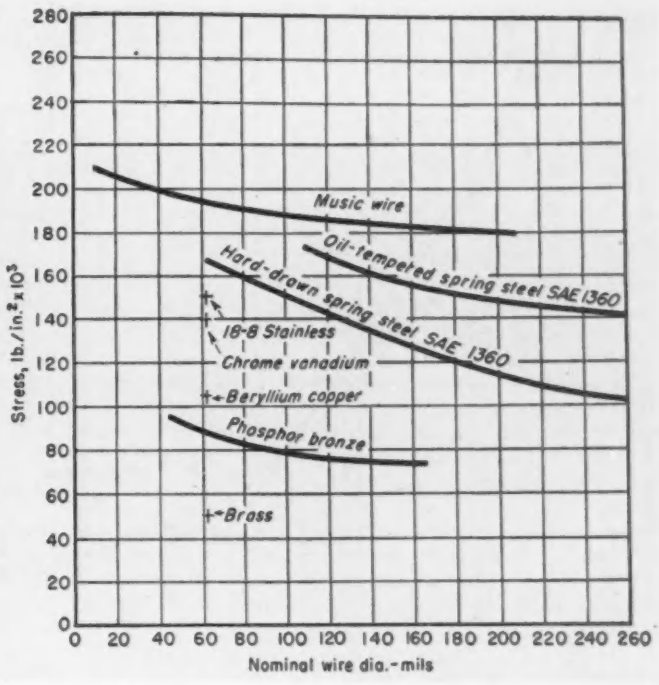


Fig. 2—Maximum values of proportional limit that can be induced by cold-setting different spring materials. See Fig. 1 for a graphical explanation of how these increased values are obtained with compression type units.

The category into which a given spring is placed is determined by comparing the calculated stress at solid height with the proportional limit stress produced by cold-setting. For example:

(1) If the calculated solid stress is less than the proportional limit stress, cold-setting is not possible.

(2) If the calculated solid stress is greater than the proportional limit stress but less than the maximum proportional limit stress with cold-setting, the spring usually will be cold-set.

(3) If the calculated solid stress is greater than the maximum proportional limit stress with cold-setting, the spring will not be cold-set.

Extension Springs

All extension springs are stress relieved to remove the residual bending stresses produced by the coiling operation but are seldom cold-set.

Torsion Springs

Torsion springs are neither stress relieved nor cold-set. The residual stresses produced by the coiling operation increase the proportional limit when the springs are properly loaded.

Wire Retainer Rings

The treatment generally given to wire retainer type springs depends on the characteristics of the loading—whether outward loading tending to increases, or compressive loading tending to decrease the relaxed diameter of the spring.

A ring formed by bending to the final diameter in one operation is not pressive relieved when designed for compressive loading. For outward or tensile loading, a ring formed in this manner is stress-relieved. If the unit is formed to final size by cold-setting from a smaller diameter, it is stress relieved for compressive loading; but is not when loading is to be outward.

Flat Springs

Flat springs are commonly formed by bending flat stock into a specified angle, usually obtuse. When loading will be in the same direction as forming, the spring is not stress-relieved. However, when the loading will be in the opposite direction, stress-relieving is commonly used.

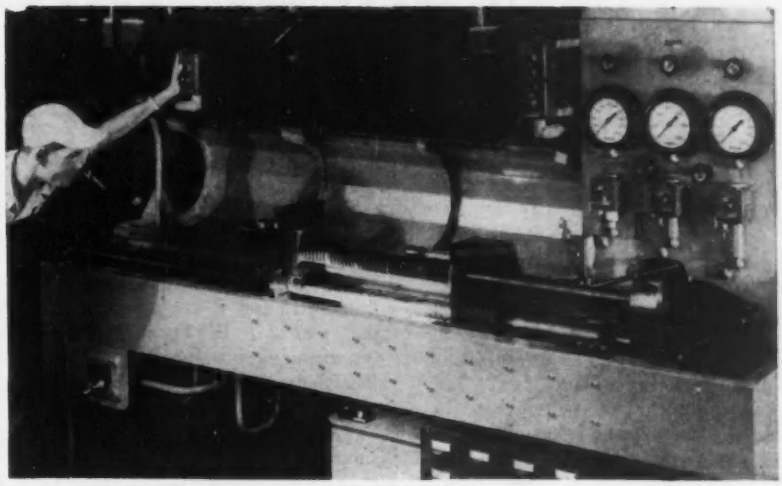


Fig. 3—Five high-gradient compression springs shown above are being compressed simultaneously to solid height after being stress relieved.

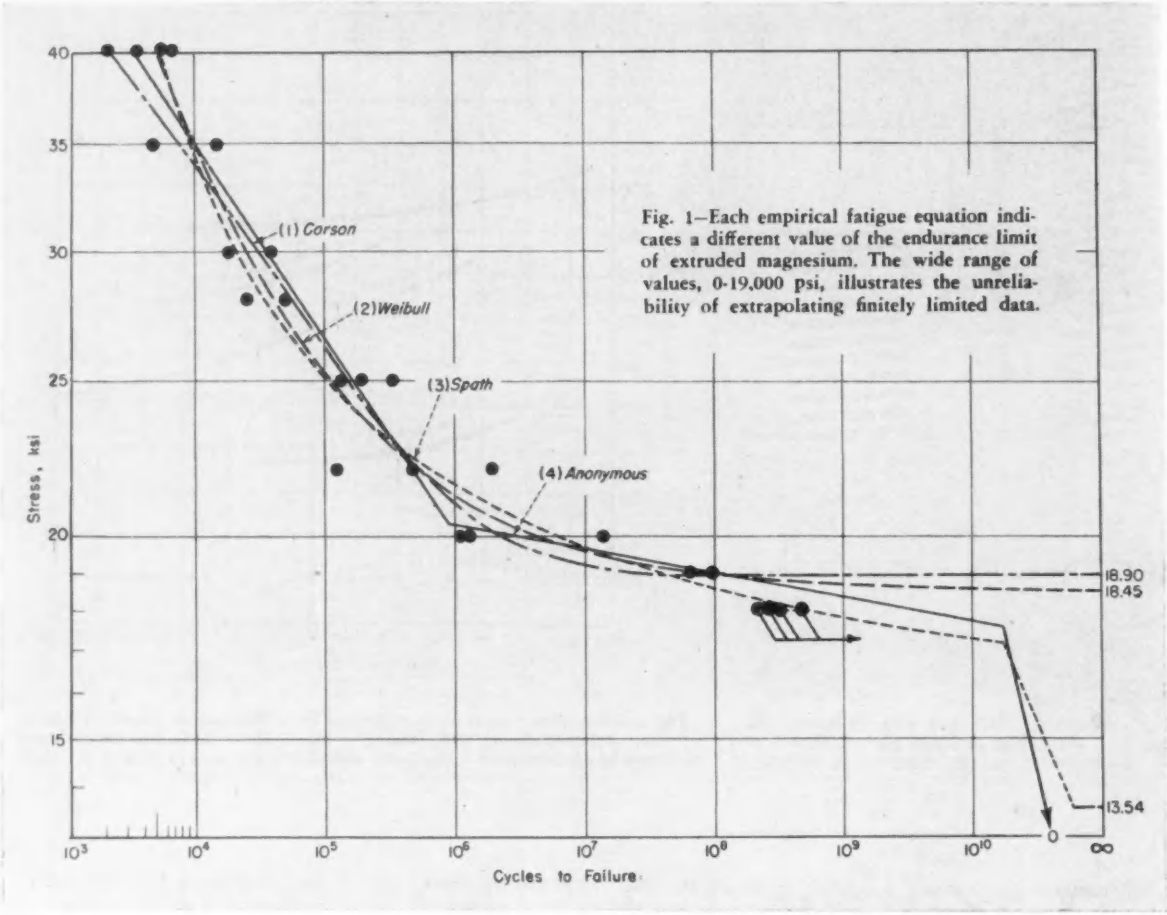


Fig. 1—Each empirical fatigue equation indicates a different value of the endurance limit of extruded magnesium. The wide range of values, 0-19,000 psi, illustrates the unreliability of extrapolating finitely limited data.

A Critical Look At Fatigue Equations

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Metallurgical Laboratories
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BECAUSE IT IS OFTEN IMPRACTICAL to test a material for an infinite number of cycles, investigators have proposed numerous emperical methods of describing the stress-number of cycles or S/N relationship. The purpose of these methods is the extrapolation to infinity of limited test data. The maximum value of stress that the material can withstand for an infinite number of reversals is usually defined as the endurance limit. For testing purposes, 10^6 stress reversals are often considered as a practical indication of infinite life.

Corson[1] has proposed that the S/N relationship can be described by the equation,

$$N = \frac{A}{(S - E)\ B^{(S-E)}}$$

where S and N have their usual significance, A and B are arbitrary constants, and E is the endurance limit. From average test values of N at three stress levels, the value of E as well as A and B, can be calculated.

A different approach is made by Weibull[2], who suggests a plot of log $(S - E)$ vs log N, for which the S/N relationship is presumed to appear as a straight line. This is equivalent to saying that the following equation applies:

$$N = \frac{A}{(S - E)^B}$$

The symbols have the same meaning as before. Weibull's procedure is to determine E by trial and error, such that the plot of data comes closest to a straight line.

Späth[3] has devised a method of plotting that permits a graphical extrapolation for the endurance limit by means of an inverted scale. He suggests a plot of S vs $1/(\log N - A)$. The zero of his abscissa thus represents an infinite number of stress reversals. By juggling of the constant A, the data are made to describe es-

sentially a straight line, which is then extrapolated to zero on the abscissa scale. Such a straight line can be described by the equation,

$$\log N = A + \frac{B}{S - E}$$

Dr. Spath proposes that significant savings in time and effort can be obtained with his method since only two or three test points are usually sufficient and since these test points can be taken under stress conditions that require comparatively few reversals. Also, it is claimed that this method will yield a clearly defined endurance limit for alloys, such as aluminum, which have shown little tendency toward a horizontal course when plotted on a conventional basis.

All three of these methods make the tacit assumption that if the S/N behavior can be described mathematically within the range covered by test data, the mathematics of the curve will remain unchanged from there to infinity. Unfortunately, there are a multitude of possible ways to describe the known part of the curve, and they do not all lead to the same description of the unknown part. While graphical research is often justified by nature's tendency to operate according to regular patterns, and indeed may be an invaluable technique in engineering investigations, it appears in this case that it is still not possible to define the pattern with confidence.

To demonstrate this, a set of test data on extruded magnesium alloy *ZK60A-F*[4] was selected, and fits to the data were made by each of the three equations described above, and also by the two straight lines widely used to describe test data on a log-log S/N plot. To eliminate prejudice, the trial-and-error and visual techniques were abandoned in favor of a least-squares analysis. The results of the plotting are presented by the curves of Fig. 1 and also have been summarized in tabular form below.

The last value of root-mean-square error in the table is for a random curve, or for some equation with eight arbitrary constants, drawn to pass through the mean value of log N at each stress level for which there are test points. This represents the best possible fit for any single-valued function since it is a measure of the scatter of the test points themselves. Comparison of this value with those above it indicates that all the curves are near-perfect fits to the data, a conclusion that is readily confirmed by Fig 1. The graphs also shows that although the four run-outs at 18 ksi could not be included in the analysis, they remain consistent with all the curves determined. Yet the four curves show values of endurance limit ranging all the way from zero to 19 ksi. *An equation was hardly needed to prove that the endurance limit lay in this range.*

The fact that the first two equations yield nearly identical values of E cannot be construed as a check on the validity of either of them. Both are completely arbitrary, and it seems clear that similar arbitrary equations could be found that would yield any chosen E-value. It might be argued that the two-straight-line method does not deserve to be included in this comparison because it involves a discontinuity of slope. Similar discontinuities are not unknown in nature. So little is known of the true nature of fatigue that it is unlikely at present that anyone can produce conclusive evidence that a change in the mechanism of damage, corresponding to the discontinuity, does not occur. Furthermore, if one should choose to ascribe significance to the relatively minor differences in root-mean-square error, it will be seen that the fit by the method of two straight lines is the best of the four methods.

The comparison of these four methods of describing the S/N relationship has shown only that the endurance limit lies somewhere within the range that had already been known to include all possible values. Thus, reliance on any one of them, or on any equation not founded in established fact, is dangerous and can lead to misconceptions. It might be argued that checking these curves against a single set of data is not sufficient to invalidate their use for other materials. It is not the intention, however, to provide a catalog of good and bad fits by the several equations on various alloys. The example has been shown merely to illustrate the point, not to justify it. As long as fatigue equations remain in the realm of pure curve-fitting, their use can provide no reliable information that the data points themselves have not already revealed.

Empirical fatigue equations are unreliable and often misleading. This is demonstrated by the application of four such equations to test data for a magnesium alloy. The results are shown in the graph, left. Values of the endurance limit range from 0 to 19,000 psi for the same material, depending on which of the four equations is used.

Table I–RESULTS OF CURVE-FITTING FATIGUE DATA FOR MAGNESIUM

Reference	Author	Equation N=No. cycles S= Stress	Endurance Limit	RMS Error in Log N
1	Corson	$N = \frac{3{,}076{,}000}{(S-18.90)1.226^{(S-18.90)}}$	18.90	0.37
2	Weibull	$N = \frac{13{,}900{,}000}{(S-18.45)^{2.610}}$	18.45	0.36
3	Spath	$\text{Log } N = 2.683 + \frac{26.58}{S-13.54}$	13.54	0.40
–	Anon.	$S \geq 20.34$: $\text{Log } N = 16.94 - 8.398 \log S$ $S \leq 20.34$: $\text{Log } N = 92.39 - 66.07 \log S$	0	0.34
Random Curve Through Mean Values of Log N				0.32

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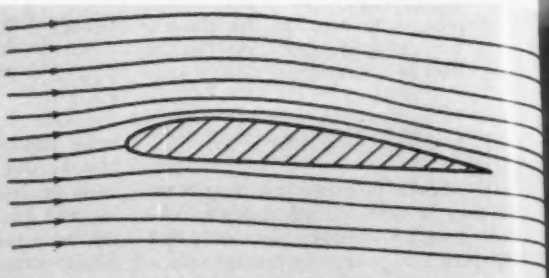
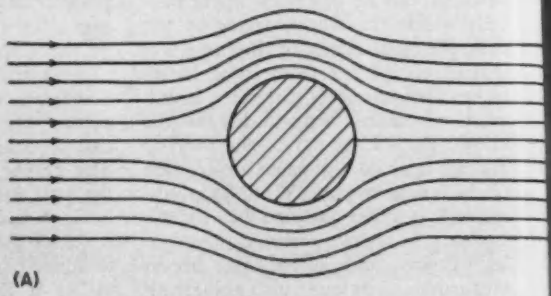
Significance of Separation in

Hydrodynamic Design



(A)

Fig. 1—(A) Flow of air past an aircraft wing at a low angle of attack; the pathlines of individual air particles conform closely to the contour of the wing. (B) Separating flow of air about an aircraft wing at a high (stalling) angle of attack;



(A)

Fig. 3—(A) Theoretical flow of an ideal frictionless fluid about a cylinder. (B) A separating flow about the same

Causes of separation and its effects in fluids that flow at a high velocity. Methods for detecting and reducing separation in flow systems. Importance of streamlining in avoiding turbulence and the effectiveness of guide vanes in reducing losses at pipe bends. Ideal and real flow in conduits. Techniques for controlling and moving the boundary layer downstream to reduce the pressure drag.

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MUCH OF THE KNOWLEDGE GAINED in theoretical and experimental work on separation, although centered in the field of aerodynamics, is rapidly being applied to hydrodynamic design.

Many difficulties encountered in the design of hydrostatic devices such as pumps, motors, valves and controls are really hydrokinetic in nature. Wherever fluids flow at high velocity, separation is likely to be present. A consideration of this phenomenon, therefore, is usually advantageous in obtaining the optimum design.

The term separation has a special meaning in the fields of hydraulics and fluid mechanics. In these fields, separation refers to that form of fluid motion in which the fluid pathlines do not parallel the solid boundary past which flow takes place.

A common example of separation is the "stalling" of an aircraft wing when flown at too high an angle of incidence. At low angles of attack, as shown in Fig. 1 (A), the pathlines of individual air particles conform closely to the contour of the wing. At and above a certain critical angle of attack, Fig. 1 (B), these particles no longer follow the wing contour; a severe eddying or recirculatory turbulence forms along the top of the wing, reducing wing lift and increasing drag.

An excellent example of separation in liquid flow is that which occurs in diffusers of too wide an angle of divergence. When this angle is too great, the main stream of the liquid separates from the diffuser walls and an intense eddying turbulence is created in the downstream end as shown in Fig. 2. A similar condition occurs when gases flow through a diffuser of excessive divergence.

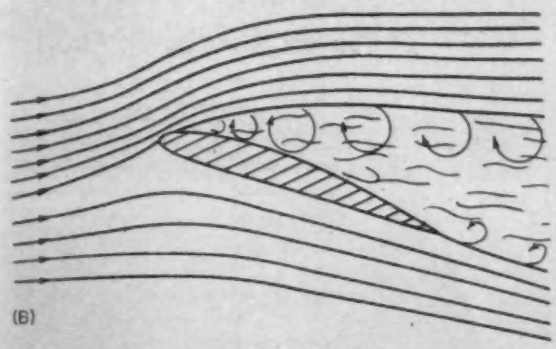
Separation is a discontinuity of flow in the sense that particle pathlines may lose complete similarity to those indicated by purely theoretical considerations. The theoretical flow of an ideal frictionless fluid about a cylinder is compared in Fig. 3 with a separating flow about the same cylinder. The space between the solid boundary and the continuous pathlines in Figs. 1 (B), 2 and 3 (B) is filled with fluid.

Cavitation, in contrast, is not only a discontinuity of flow, it is also a discontinuity of fluid. In cavitation certain flow areas are filled, not by the fluid, but by vapor bubbles of that fluid. Because of this distinction, it is apparent that cavitation is a malady peculiar only to liquids.

The presence or absence of cavitation is dependent upon the static pressure of the liquid. Vaporization, hence cavitation, cannot occur except at those points in the flow system where the static pressure of the liquid is at or below the vapor pressure of the liquid.

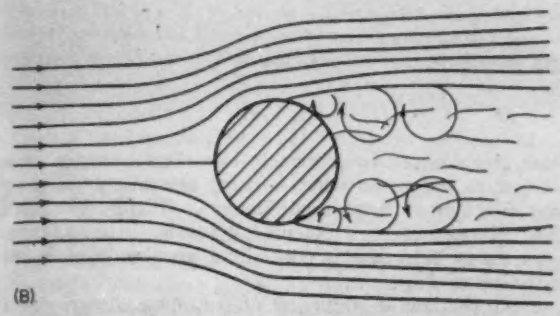
In a closed hydraulic system, such as the hydrokinetic torque convertor, cavitation can generally be avoided by operating the entire system under a mean static pressure sufficiently high to maintain local pressures greater than the vapor pressure of the liquid.

Separation is independent of static pressures. It depends



(B)

air particles do not follow wing contour; a severe eddying or recirculatory turbulence forms along the top of the wing and reduces lift.



(B)

cylinder. Between the solid boundary and the continuous pathlines, the particle pathlines separate from main stream.

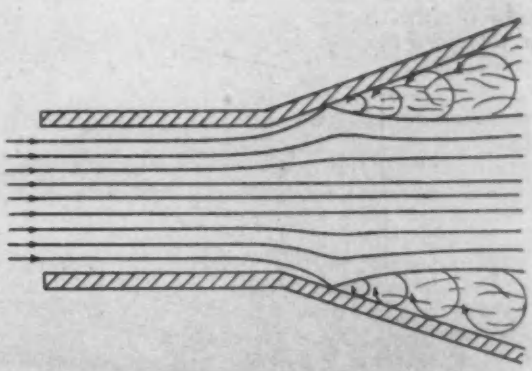


Fig. 2—Separating liquid flow through a diffuser where the angle of divergence is too great to maintain streamline flow in the downstream end of the expanding diffuser.

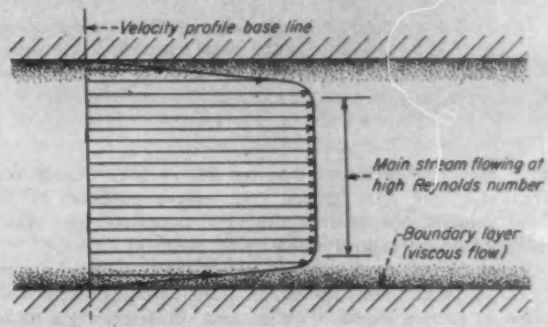


Fig. 4—Idealized velocity profile for flow in a pipe or other conduit depicted by Prandtl's boundary layer theory.

upon the shape of the boundary past which the fluid is flowing, the roughness of the boundary surface, and the Reynolds number.

The Reynolds number is a dimensionless ratio characterizing fluid flow conditions. In effect, it is the ratio of the relative magnitudes of inertia forces to viscous forces. As such, this concept is important in analyzing the causes of, and cures for, separation.

Where:

V = velocity of fluid
D = significant linear dimension of boundary
ρ = mass density of fluid
μ = viscosity of fluid
N_R = Reynolds number

Reynolds number expressed algebraically is

$$N_R = \rho VD/\mu$$

Another significant difference exists between cavitation and separation. Cavitation generally makes its presence known either by noise or by erosion of the hydraulic device in the critical areas, or by both. These symptoms result from the relatively violent collapse of vapor bubbles as they are carried downstream into regions where static pressures exceed the vapor pressure.

Separation, however, is a comparatively sly villain. Often the only external evidence of separation is the presence of excessive heat, which frequently can be detected only by careful instrumentation. The only certain manifestation of separation is reduced performance. Separation is always accompanied by a loss of energy as a result of the heat generated in the violent eddies. In liquids, this heat is an irrecoverable energy dissipation.

Separation exists frequently in torque convertors, pumps, turbines, manifolding, and hydraulic fittings.

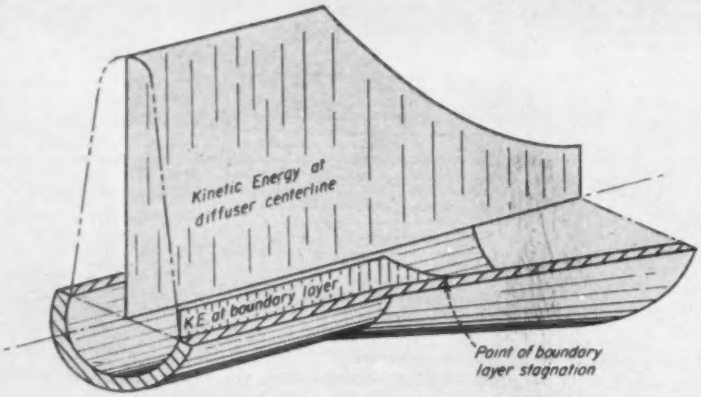
The Boundary Layer

The classical mechanics concept of an ideal frictionless fluid, which pictures the flow in any system as purely the result of potential differences, does not allow for the presence of eddies. The potential flow pattern does not even permit the existence of drag. This and similar anomalies bothered Jean d'Alembert enough to prompt the statement that "The theory of fluids must necessarily be based upon experiment." The enormous difference between ideal flow and actual flow has been termed the d'Alembert Paradox.

The basic difference between ideal flow and real flow is that all real fluids have finite viscosities that directly or indirectly cause all drag forces and fluidynamic losses.

Drag forces and their resultant losses are generally broken down into two component types. One type is skin friction, which results from the shear forces transmitted from the fluid to the body (or vice versa) by the viscosity of the fluid. The second type is that caused by separation, sometimes referred to as pressure drag. In poorly designed fluidynamic devices, pressure drag can be much greater than skin friction. These two types of drag are additive in determining the total drag or loss.

For a given hydraulic machine, rather distinct limits



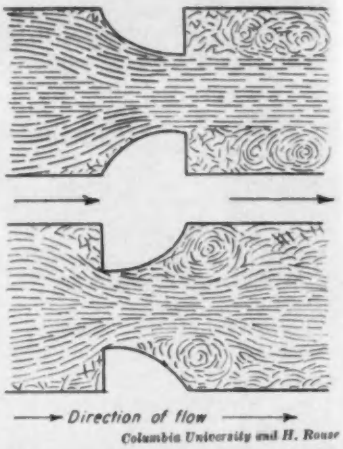


Fig. 5 (Left)—Kinetic energy profiles in a diffuser under separating conditions where no energy is supplied externally. Fig. 6 (Right)—Sketches made from classic photographs showing comparative effects of accelerative and decelerative flow. In both sketches, the flow is from left to right. The greater orderliness of the accelerating flow is qualitatively evident.

exist as to the measures that can be taken to reduce skin friction. The skin friction is largely a function of the fluid velocity, the area of the solid boundary past which the fluid flows, and the viscosity of the fluid.

In numerous designs, from one to three of these parameters are completely inflexible. In particular, the fluid viscosity is often fixed. For instance, in designing a pump for a water system, little can be done to decrease the viscosity of the water. By designing for minimum surface area and minimum relative velocities, however, it might be possible to improve the pump performance.

The inefficiency associated with separation manifests itself as a loss of pressure resulting from the energy dissipation in the whirlpools indicated in Figs. 1 (B), 2 and 3 (B). For a body moving submerged in a fluid, the pressure on the nose of the object, therefore, is greater than on its rear. The resulting unbalanced force is known as pressure drag. When the fluid flows within diverging solid boundaries, the lack of pressure recovery means that additional energy must be supplied to push the fluid through the passage.

Fundamentally, Prandtl's boundary layer theory pictures the fluid stream as divided into two portions: (1) A thin layer known as the boundary layer, adjacent to the solid surface; and (2) The remainder of the fluid at a distance from the surface.

In the boundary layer, the velocity gradient (normal to the boundary) is high enough so that, even though the fluid viscosity may be small, the viscous forces are of considerable magnitude. The viscous forces are, of course, the product of the viscosity and the velocity gradient. The primary cause of separation is closely related to the behavior, or misbehavior, of this boundary layer.

In the fluid at a distance from the surface, the inertia forces are presumed to be so great and the viscous forces so insignificant in comparison that the fluid essentially follows the pattern defined by potential flow theory.

The condition as shown in Fig. 4 corresponds to that of low Reynolds number flow near the boundary surface and an extremely high Reynolds number flow in the main portion of the stream.

Prandtl's hypothesis for the cause of separation is that since the boundary layer moves very slowly and is therefore characterized by extremely low kinetic energy, it is subject to stagnation when a rising pressure gradient in the direction of flow is encountered. Fluids, like heat, flow in response to a potential gradient. The potential gradient in fluid flow is generally a pressure drop in the direction of flow.

From the law of continuity of streaming energy, stated by Bernoulli, the pressure in any hydraulic system increases when the velocity decreases; for instance, by increased cross sectional flow area. Such a diverging system, then, results in a rising pressure gradient in the direction of flow.

To flow against such a pressure gradient, the fluid must constantly give up kinetic energy or receive energy from an external source as in pumps and compressors. For the flow in a diffuser, as shown in Fig. 5, where no energy is supplied externally, the main body of the fluid must draw from its supply of kinetic energy to flow against the pressure gradient. As Fig. 5 indicates, the boundary layer does not have enough kinetic energy to maintain flow in the layer. When the boundary layer kinetic energy is exhausted, the boundary layer velocity must naturally be zero.

The result is a narrow band of fluid, the velocity of which is zero, immediately adjacent to the edge of the main stream, which has a significant finite velocity. Theoretically, an infinite velocity gradient exists between the two portions of fluid. Thus, the shear stress is enormous; and the main stream, in passing the stagnant boundary layer, picks up the stagnant particles and starts them whirling downstream.

This action destroys the normal pattern of flow. Downstream from the point of separation initiation (stagnation point of the boundary layer), the main stream of fluid is confined to a rather restricted area, and on both sides of it the space is filled with small high speed whirlpools, or vortices. It is apparent that considerable energy is dissipated as a result of this disorganized motion.

It has been pointed out that a rising pressure gradient can stagnate the boundary layer and result in separation. It is of interest to consider the opposite condition in which the pressure gradient is falling.

In a converging nozzle, the cross sectional area decreases in the direction of flow, the main fluid velocity increases,

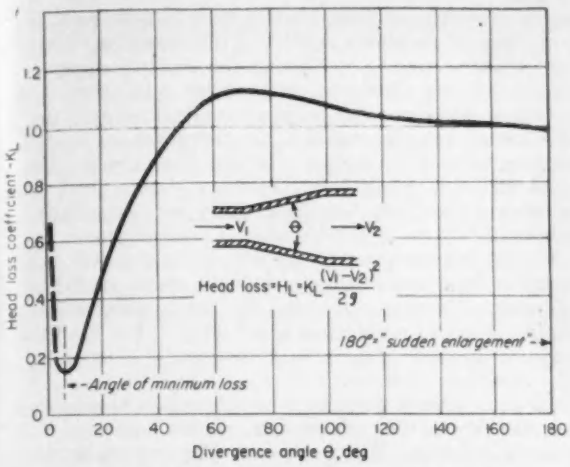


Fig. 7—Variation in diffuser loss coefficient as the angle of divergence increases. The loss increases rapidly with divergence angles smaller than seven degrees.

and by Bernoulli the static pressure decreases. In this instance, the boundary layer has the opportunity for a free ride, it can take kinetic energy from the stream if conditions are not too severe.

The extreme example of a converging or accelerating passage is found in the sudden contraction. In this case, even though conditions are favorable for accelerating the boundary layer, some separation may result from the presence of the vena contracta. As the fluid leaves the region of the vena contracta and expands to fill the passage, the accompanying increase in the static pressure sometimes causes separation.

The preceding discussion can be generalized in a rule of thumb that, unfortunately like most other such rules, has several exceptions. The rule is: Fluids can be accelerated much more efficiently than they can be decelerated. This rule derives from the foregoing explanation that acceleration is accomplished in a converging (dropping pressure gradient) passage, which stimulates flow of the boundary layer; while deceleration is accomplished in a divergent (rising pressure gradient) passage, which discourages boundary layer flow. Any time the boundary layer stops completely, separation is the inevitable result. Wherever there is separation, there is loss and inefficiency.

An example often given of the comparative losses in accelerative and decelerative systems is a water turbine and a pump. Turbines are ordinarily more efficient than comparable pumps because the pressure gradient in the turbine is inherently a falling one, while that in the pump is a rising one. This phenomenon can be seen more dramatically in Fig. 6, which shows the flow through a passage of varying cross section, first in one direction, then in the other. The greater orderliness of the accelerating flow is qualitatively evident.

Practical Examples of Separation

Separation is a phenomenon that abounds in and around hydro- and aerodynamic equipment such as fans, vacuum cleaner impellers, pumps, internal combustion engine manifolding, automobile bodies, valves, ducts, and elbows, to mention but a few instances.

The simplest example is the diffuser, or diverging pipe section. It has been shown experimentally that an approximately 7 deg included angle of divergence results in maximum diffuser efficiency. At smaller angles the added axial length necessary for diffusion between two diameters becomes great enough to affect the losses adversely by amplifying the skin friction. At larger angles, the pressure gradient is so steep that boundary layer separation occurs.

The curve in Fig. 7 indicates that the loss increases more rapidly with angles smaller than 7 deg than with larger angles. This variation, of course, merely reflects the rate of increase of the cotangent at small angles. The loss in a sudden enlargement (180 deg included angle) is actually less than that in a diffuser of 60 deg included angle. If the fluid were run through the pipe in the opposite direction, the loss of the sudden contraction would be less than half that of the corresponding sudden enlargement.

Another common loss that in a large measure is caused by separation occurs in elbows and bends of pipes and ducts, although in such flow an additional loss factor is present. This factor, called secondary flow, refers to the fluid flowing around the bend in spirals because of centrifugal forces. Secondary flow is the one exception that might cause excessive losses in a fluidynamic machine after surface area, velocity, and separation have been reduced as much as possible.

Secondary flow is the result of transverse pressure gradients in the flow passage. It can be minimized by controlling the transverse gradients through proper design of passage shape, or through the use of guide vanes that prevent cross flow.

Both separation and secondary flow cause losses in bends and elbows. The loss in a 90 deg standard elbow, for instance, approximately equals the friction loss in a length of thirty-six diameters of the same size straight pipe. Losses in valves, manifolds, and hydraulic fittings are also likely to be quite severe. Globe valves are among the worst offenders in this respect, embodying as they do a tortuous fluid path from inlet to outlet.

Smoothness and continuity of boundary shape, in general, result in minimizing adverse pressure gradients, and thus separation. Smoothing or fairing the boundaries of a flowing fluid so as to control the pressure gradients is commonly called streamlining. The greater the relative velocity between a fluid and a solid boundary, the more important streamlining becomes.

In hydrokinetic machinery, as the name implies, the kinetic energy and velocity are usually high, hence skin friction and separation are usually critical. Hydrostatic machines, on the contrary, are designed to operate using low kinetic energy combined with high potential energy (pressure).

One of the disconcerting effects of separation in fluidynamic machinery is the resulting loss of control of the flow direction. Most hydro- and aerodynamic devices are critically susceptible to changes in the direction in which the fluid approaches a set of vanes. Separation in one set of vanes can completely change the direction of the discharging flow and initiate serious losses at the point of entrance to the next set of vanes. Separation is quite common in fans and in the vane passages of centrifugal pumps.

In the torque converter, which is currently popular in automotive transmissions, the problem is especially severe because the angle of incidence of the oil on the blade noses keeps changing with the speed and tractive effort of the automobile. If the blades are designed for no separation at one speed, they are likely to suffer separation at speeds above or below that speed. The same difficulty exists in the compressors and turbines of turbo-jet and turbo-prop engines. Axial flow compressors are particularly critical

in this respect, and although generally characterized by a higher peak efficiency than centrifugal compressors, have efficiency curves that fall off rapidly either side of the design point, largely because of separation.

Detection of Separation

Separation may often be difficult to detect because it does not advertise its presence loudly except in the generation of heat and reduction in efficiency. There are, however, several common cases in which separation is visibly present. One is in the surface wake of a square stern rowboat. As the water arrives at the stern, it finds the equivalent of a sudden enlargement. As a result, the boundary layer, instead of following the contour across the stern, separates and initiates a series of eddies. Another common instance is manifested by an automobile exhaust pattern on a cold day. Still another is the wake immediately downstream from a bridge pier in a rapidly flowing stream.

These three familiar examples point to a practical technique for detecting the existence and relative severity of separation, that is, to make the paths of individual fluid particles visible. The methods employed for visualizing flow depend upon the type of fluid being studied, the type of test circuit employed, and several other variables.

When dealing with gases such as air at velocities less than 400 ft per sec, the usual technique is to introduce visible particles into the air stream. Different kinds of smoke are widely used in this manner as well as certain vapors such as that of kerosene.

At high gas velocities approaching or above the velocity of sound, several purely optical systems are employed. These systems detect differences in air density by the effects of these differences on the light-transmitting properties of the air, and thus do not require the addition of smoke or vapors.

In studying liquid flow, some form of additive is generally necessary. To make certain that the particle paths are identical with true fluid paths, particles added to the liquid should have nearly the same density as the liquid, or be small enough so that surface forces are large compared to inertia forces. One such additive for use with water is a mixture of carbon tetrachloride and glycerine. This mixture forms discrete globules, the paths of which can be recorded photographically because of the differences in refractive index. For low velocity laminar flow, streamers of colored dye can be added.

A two-dimensional approximation can sometimes be made by using free surface flow with highly reflective particles scattered on the liquid surface. Care must be exercised in generalizing from this type of experiment because of the possible effects of gravity and surface tension, neither one of which is present for flow around a fully submerged body, or flow in a closed conduit.

These and numerous other visual techniques can be utilized for indicating the presence or lack of separation. If carefully executed, they give a satisfactory measure of the relative severity of separation. Visual study of the corresponding flow patterns is often an aid in evaluating design improvements.

Methods for Reducing and Obviating Separation

Separation, it will be recalled, generally occurs as the result of the existence of a rising pressure gradient accompanying decelerative flow. A natural approach wherever possible, therefore, is to design for accelerating flow, or at least for controlled deceleration (streamlining). From the study of the diffuser, a designer can utilize the information that divergence up to approximately 10 deg will not cause excessive losses. Further, if the construction of the fluidynamic device is such that divergence is an absolute necessity, and this divergence cannot be reduced below 40 deg, it is evident from Fig. 7 that there is little point in attempting to streamline at all. If it is more convenient from a manufacturing standpoint, the designer might as well use 180 deg divergence, or a sudden enlargement.

Also, it is obvious that tolerances on mating parts that form a fluid boundary should be so arranged that a sudden contraction can occur but not a sudden enlargement. The actual efficiency gains from individual criteria such as stated may be small, but these gains are accumulative and should at least be considered in the design process.

In many instances, particularly those associated with flow around corners, guide vanes reduce the losses caused by separation. The reduction in loss that can be effected with properly designed guide vanes is indicated in Fig. 8. This particular example, Fig. 8, is complicated by secondary flow as well as separation.

The exact ratio of the gains from guide vanes in reducing secondary flow to those obtained in reducing separation has yet to be evaluated. The guide vanes, however, are helpful in reducing bend losses. This type of construction is commonly employed in wind tunnels to reduce losses and maintain uniformity of flow. With guide vanes such as those described, it is possible to use sharp elbows without excessive losses. Obviously, in many small elbows it is structurally impracticable to include such vanes.

In a study of the fundamental cause of all separation, which is the boundary layer, several other methods for improving flow efficiency present themselves. One method that is receiving much attention from aeronautical engineers, and that should before too long be adapted to hydraulic applications, is the art of boundary layer removal.

Boundary layer removal is the technique of placing small slots or apertures through the wall of the solid boundary just upstream from the point of boundary layer

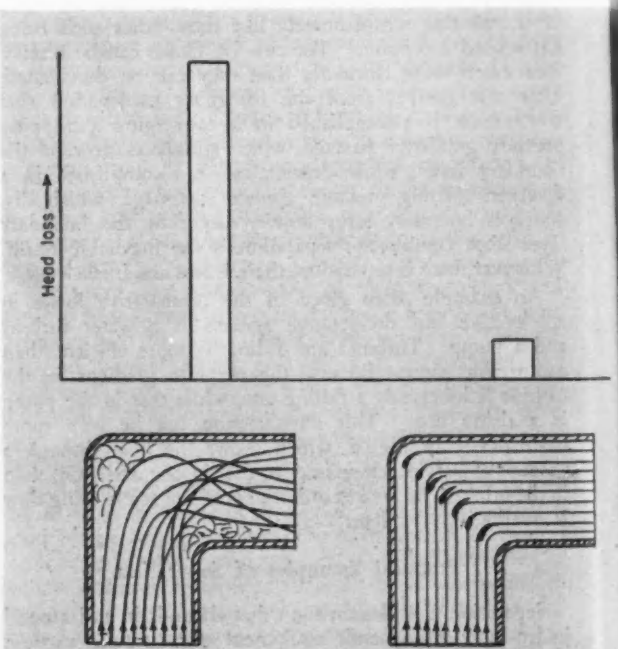


Fig. 8 — Comparative head loss for flow through an elbow without guide vanes and an elbow with guide vanes.

separation, and applying a suction that bleeds the boundary layer away. The result of such action is that a new boundary layer must form downstream from the slot. The new boundary layer, however, commences life with a kinetic energy nearly that of the main stream of fluid. By the time that its kinetic energy is dissipated, the boundary layer will have moved some distance downstream. Since this process theoretically, can be repeated many times, the point of separation can thus be moved as far as is feasible to the rear of the body to achieve a reduction in pressure drag.

By removing the boundary layer with slots or apertures at one or more points along a diffuser wall, divergence angles considerably larger than 10 deg can be employed without separation. This technique is employed in some of the engine air scoop diffusers in high speed aircraft. Airplanes with similar suction slots built into the upper side of the wings can be flown at abnormally high angles of attack without stalling.

An alternative method of removing the boundary layer is to fabricate the boundary wall of a porous material, through which the slowly moving fluid can be continuously drawn along the full length of the boundary.

A diametrically opposite approach to the separation problem involves injecting a comparatively high speed jet of fluid into the boundary layer so as to activate it by the resultant mixing and momentum transfer. As indicated in Fig. 9, this method has been employed in the design of aircraft wing slots. The presence of the slot allows the wing to be flown at much higher angles of attack (resulting in correspondingly greater lift) without stalling or separation. In general, addition of high velocity fluid is likely to be more difficult to effect and control successfully than is boundary layer removal.

Another technique, one in which the rewards are great for the effort involved, is transition of the boundary layer from laminar to turbulent flow. Because of continuous momentum exchange with adjacent particles in the main stream, a turbulent boundary layer is characterized by much higher kinetic energy than its laminar counterpart. As a result of this increased kinetic energy, the turbulent boundary layer can progress against a steeper pressure gradient than the laminar boundary layer.

To achieve transition from laminar to turbulent flow in the boundary layer is not a particularly difficult task. Transition occurs naturally with typical boundary roughnesses if the Reynolds number becomes sufficiently high. The classic example of such transition is in the flow around a sphere or cylinder. If the body is moved through a fluid at successively higher velocities, the boundary layer eventually changes from laminar to turbulent. When this sudden transition occurs, the drag force decreases noticeably. In Fig. 10 is shown the manner in which the drag coefficient of a sphere varies with Reynolds number; and thus with velocity, assuming the fluid viscosity to remain constant.

In most practical designs, however, operation will be at a Reynolds number well below the critical value corresponding to boundary layer transition. It then becomes necessary to bring about the transition synthetically; sometimes it can be accomplished by roughening the boundary surface ahead of the point of separation. The roughness, if properly located and of the correct degree, excites the boundary layer to turbulence and results in a reduced pressure drag.

It should be kept in mind, however, that skin friction will be increased by boundary layer transition since a turbulent boundary layer demonstrates a higher transverse velocity gradient (and hence, higher shear stresses) than a laminar layer. Thus, where considerable boundary area is involved, and only slight initial separation, losses could be increased by injudicious boundary layer transition.

All the foregoing techniques for controlling the boundary layer are still more art than science. Experimentation is therefore necessary to cope successfully with the boundary layer in particular designs.

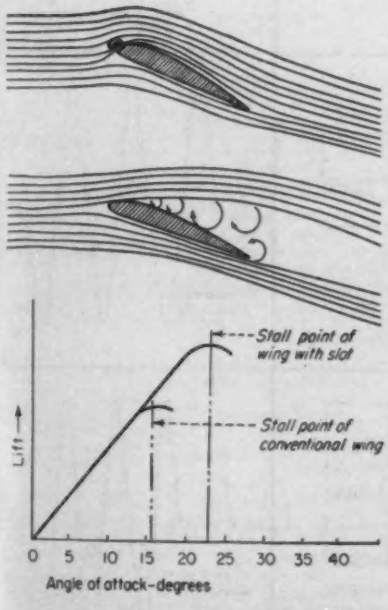


Fig. 9—Effect of leading edge slot in allowing high angles of attack without stall or separation.

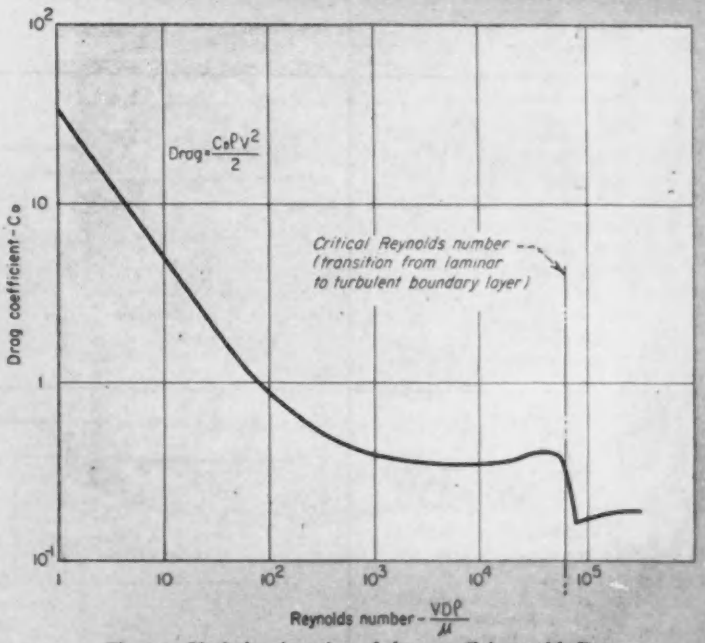
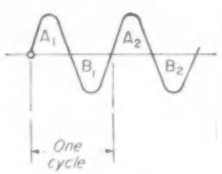
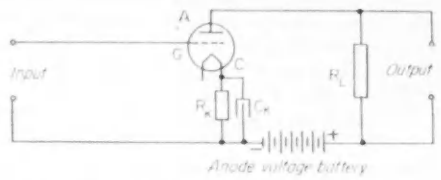
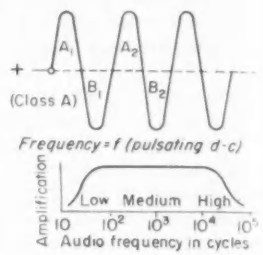
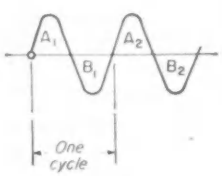
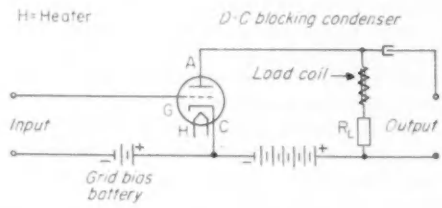
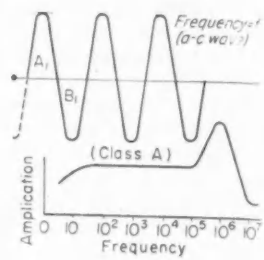
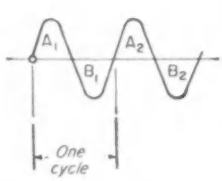
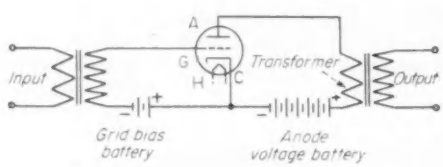
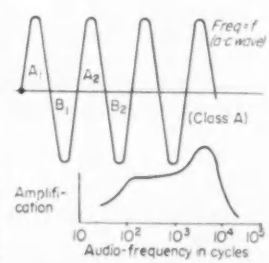
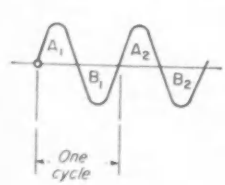
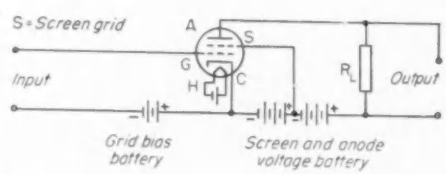
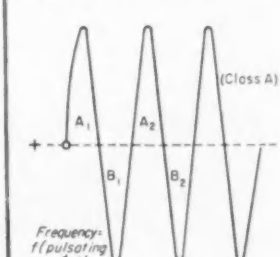
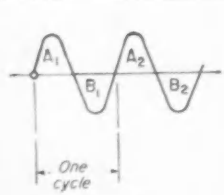
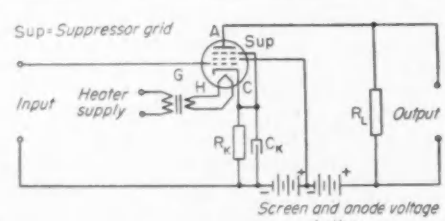
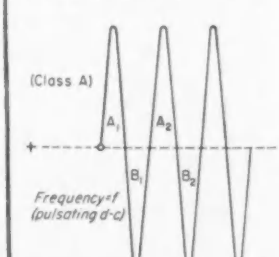


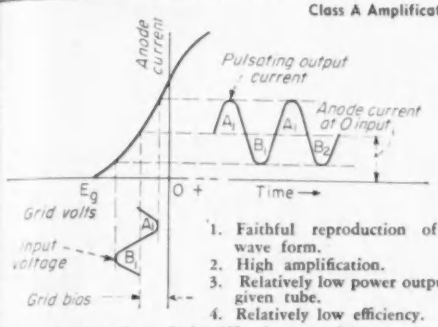
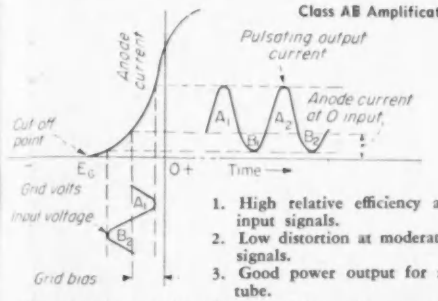
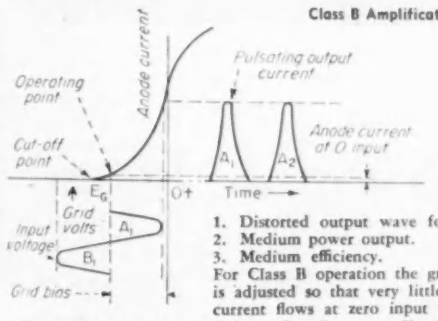
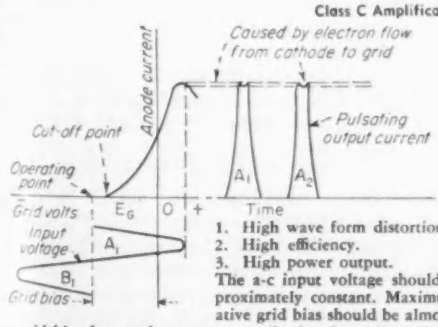
Fig. 10—Variation in value of drag coefficient with Reynolds number for flow past a sphere.

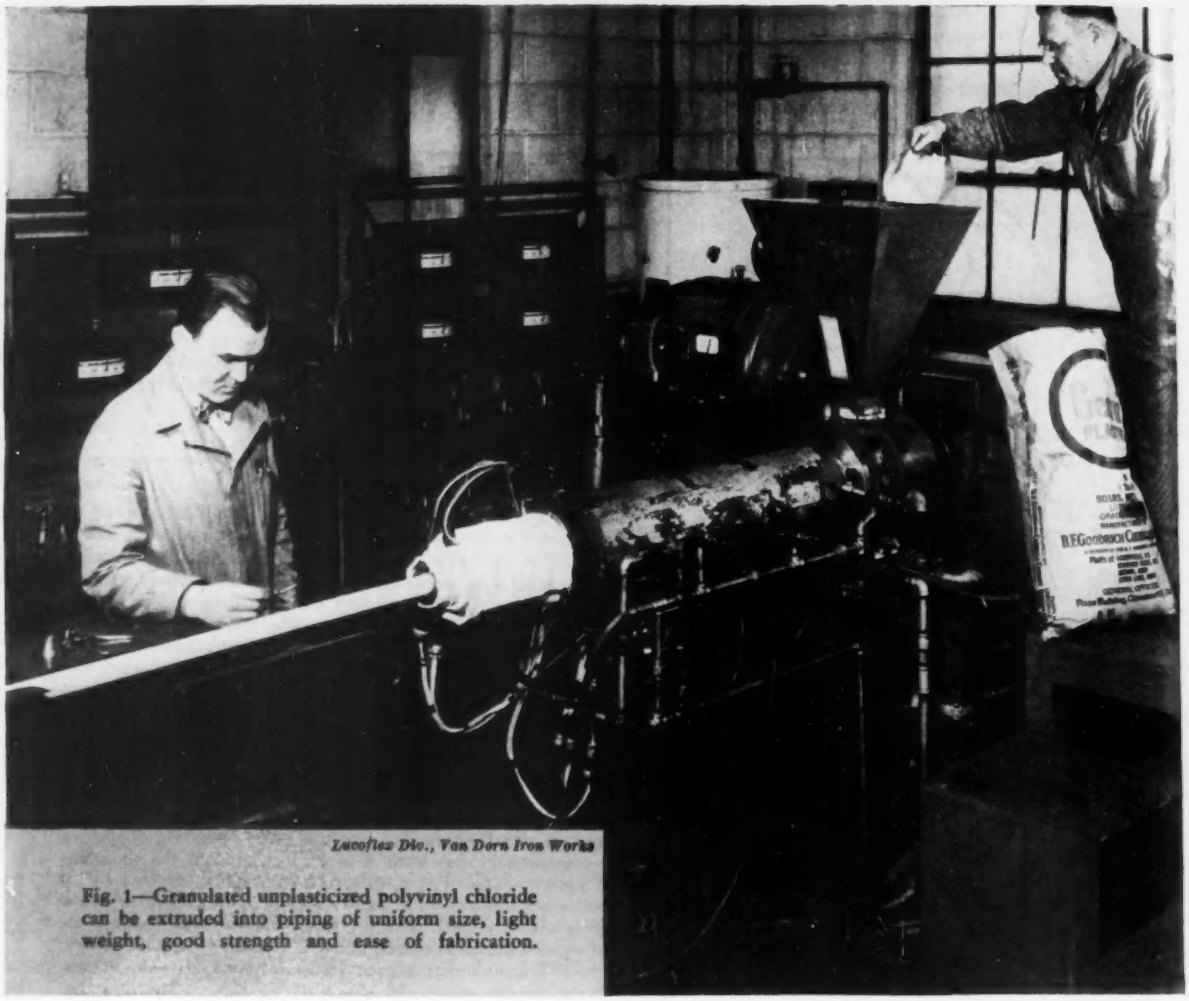
Voltage Amplifiers

Type	Input Voltage	Circuit Sketch	Output Voltage
Single Stage, Resistance Load, Voltage Amplifier (Triode)	 f = Frequency (a-c sine wave)	 A = Anode, G = Grid, C = Cathode, R_K = Grid resistor, R_L = Load resistor, C_K = Bypass condenser	
Single Stage, High Frequency-Compensated Voltage Amplifier (Triode)	 f = Frequency (a-c sine wave)	 (Grid bias suitable for Class A, AB, B, or C operation)	
Single Stage, Transformer-Coupled Voltage Amplifier (Triode)	 f = Frequency (a-c sine wave)		
Single Stage, Resistance Load, Voltage Amplifier (Tetrode)	 f = Frequency (a-c sine wave)		
Single Stage, Resistance Load Voltage Amplifier (Pentode)	 f = Frequency (a-c sine wave)	 (Cathode bias suitable for Class A amplifier)	

R. B. IMMEL
Westinghouse Electric Corporation

Fundamental Electronic Circuits

Operation (depends on grid bias selected)	Remarks
Class A Amplification  1. Faithful reproduction of input wave form. 2. High amplification. 3. Relatively low power output for a given tube. 4. Relatively low efficiency. In general, a Class A Amplifier is never driven positive, with respect to the cathode and is not driven negative to the anode current cut-off point by the input signal. Anode current flows for complete input voltage cycle.	The voltage or power of a local or remote energy source can be effectively increased by an amplifier which translates the signal into one of higher value by the control of a local power source. The amplifier classification is determined by the mode of operation of the tube with respect to the d-c and a-c grid and anode voltages, application and power output. This particular circuit is commonly used for amplification of audio frequencies (15 to 20,000 cycles). The *IR* drop across the load resistor R_L provides the output as it varies directly with the anode current. If current rather than voltage amplification is desired, the load resistor may be replaced by a current operated device.
Class AB Amplification  1. High relative efficiency at large input signals. 2. Low distortion at moderate input signals. 3. Good power output for a small tube. The grid bias may be adjusted so that only a small anode current flows at no signal input. Amplifier will operate Class A at low input voltages and approximately Class B at high input voltages. The grid may be driven positive for some modes of operation.	The frequency range over which an audio amplifier operates can be extended by the use of an inductance coil in the anode circuit. At medium and low frequencies, the resistance is negligible. However, at high frequencies the inductance resonates with the stray capacitance of the tube and wiring to maintain or increase the amplification. The inductance shifts the phase between the input and output voltages, which may be undesirable for some applications. The blocking condenser prevents the d-c anode current from flowing in the output circuit. For a given frequency range, condenser offers little impedance to a-c anode current.
Class B Amplification  1. Distorted output wave form. 2. Medium power output. 3. Medium efficiency. For Class B operation the grid bias is adjusted so that very little anode current flows at zero input voltage. Two tubes are often used in push-pull to get distortionless output.	Both the input and amplified output voltages can be increased by means of transformers. For one particular operating frequency, the transformers may have a 10:1 ratio between the secondary and primary turns. For a wide frequency range, because of the transformer limitations, a transformation ratio of two to five is quite commonly used. The d-c anode current may saturate the iron core of the transformer, but it is separated from the output because a transformer cannot transmit direct current. Transformers are not often used above 10,000 cycles. The tube and wiring stray shunting capacitance cause the hump in the amplification curve at high frequencies.
Class C Amplification  1. High wave form distortion. 2. High efficiency. 3. High power output. The a-c input voltage should be approximately constant. Maximum negative grid bias should be almost twice grid bias for anode current cut-off. Another tube and selective circuit output impedance can eliminate most of the wave distortion.	As a four element tube has a much higher amplification factor than a three element tube, the input voltages can be amplified to a still higher degree by a single stage amplifier using this tube. For still higher amplification than that possible from a single tube, the output of the amplifier can be used as the input to another similar amplifier circuit. The circuits are usually coupled through a condenser, transformer, or other means to prevent the d-c anode voltage from being applied to the grid of the succeeding tube in the amplifier network. For this type of tube, the anode voltage should be high enough to prevent operation on the "negative resistance" portion of the characteristic curve.
	Still higher amplification than that possible with a three or four element tube in a single stage amplifier can be obtained by using a five element tube. For substantial power output and high efficiency of operation, two tubes are usually operated in "push-pull" and Class B or C to minimize distortion in the output wave form.



Lucoflex Die., Van Dorn Iron Works

Fig. 1—Granulated unplasticized polyvinyl chloride can be extruded into piping of uniform size, light weight, good strength and ease of fabrication.

Rigid Vinyl—*A Structural Plastic*

Rigid vinyls, which have the same outstanding electrical and chemical properties as plasticized vinyls, possess two characteristics not found in other plastics—they have high structural strength and can be welded by techniques commonly used for metals.

PLASTICS HAVE HERETOFORE been considered unsuitable for structural applications requiring a rigid material that can be welded. Rigid vinyl, an unplasticized thermoplastic, has overcome these limitations. This matetrial has a tensile strength of approximately 8,500 psi and can be welded to produce joints that are 95 percent as strong as the base material.

The chemical, electrical and mechanical properties of rigid vinyl are superior to those of the plasticized compounds. The addition of plasticizers to the vinyls, although necessary and advantageous for formability and texture of some forms, reduces the acid, alkali, solvent, electrical, and heat and light resistance of the original polymer. The unplasticized resin retains all the characteristics of the high molecular weight polyvinyl chloride. These are

1. High tensile strength and shock resistance.
2. Light weight
3. Good resistance to acids, alkali, solvent, heat and light.
4. Good electrical resistance.

Outstanding Properties

Rigid vinyl has good tensile and impact strength between —70 F and 170 F. At 170 F the tensile strength falls off rapidly and the material is not recommended for service above this temperature.

The tensile and flexural strengths of Geon 404, B. F. Goodrich's polyvinyl

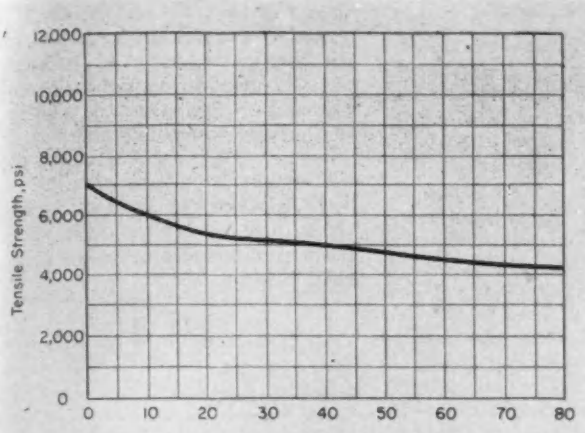


Fig. 2

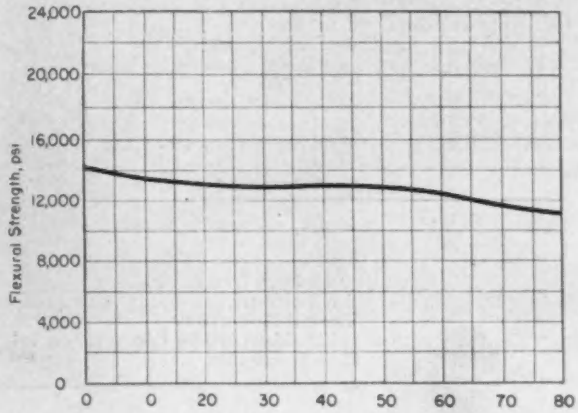


Fig. 3

Fig. 2—Variation is tensile strength of Geon 404 unplasticized vinyl with filler content.

Fig. 3—Variation in flexural strength of Geon 404 resin with filler content.

Fig. 4—Impact resistance of Geon 404 polyvinyl chloride compared to some other plastics.

B. F. Goodrich Chemical Co.

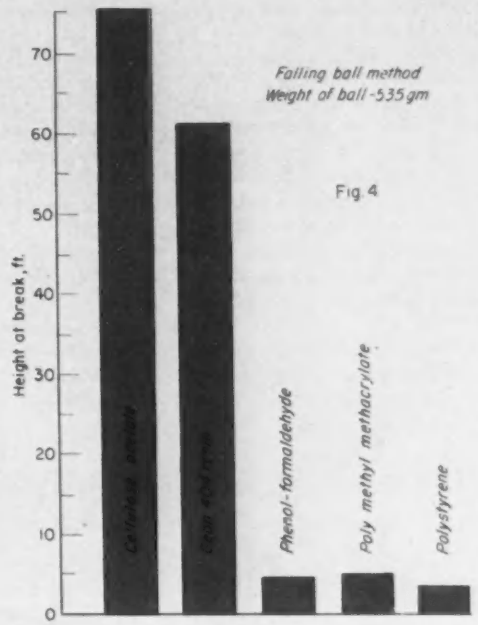


Fig. 4

chloride, are shown in Fig. 2 and 3 for varying amounts of fine particle size filler. An increase in filler content causes a decrease in both these properties, but this decrease is less than that experienced by the softer copolymer resins when loaded. The modulus of elasticity is only slightly affected by filler addition so most of the resiliency of the material is retained when it is heavily loaded.

The impact resistance of Geon 404 compared to other plastics is shown in Fig 4. A 535 gram steel ball was dropped on unsupported 6 in x 6 in x 0.025 in. samples clamped in a framework. The height of fall was increased until the sample broke. The impact strength of rigid vinyl compared closely with cellulose acetate, known among the plastics for its outstanding toughness. This test also indicated the superiority of rigid vinyl over the phenolics and polystyrene. No appreciable loss in impact strength is exhibited down to —70 Fahrenheit.

Table I lists the physical properties of Lucoflex, a rigid vinyl fabricated and marketed by the Lucoflex Division of Van Dorn Iron Works.

Corrosion Resistance. At ordinary temperatures rigid vinyl is unaffected by practically all mineral acids, bases and salts, chlorine, oil, grease, gasoline, alcohol and carbon tetrachloride. It is not subject to oxidation in the atmosphere, nor to electrolytic corrosion in aqueous solutions as are the common structural metals.

Certain types of organic solvents such as ketones, ethers, chlorinated hydrocarbons and some aromatic hydrocarbons exhibit a swelling action on the resin.

Electrical Properties. The gain in electrical properties obtained with rigid vinyl compared to plasticized vinyl is considerable. Table II lists the electrical properties of wire insulation of both materials. Outstanding among the improvements are insulation resistance and power factor, higher dielectric strength, low moisture absorption and non-flammability.

Fabrication

Rigid vinyl can be formed readily into simple or compound shapes at 280 to 300 F. Upon cooling it regains its rigidity and retains the shape to which it was formed.

Forming methods used for rigid vinyl are the same as those used for other thermoplastics. These include press forming with male and female dies, free blowing, and vacuum forming. For rolling and bending operations, the material is heated, formed around a mandrel of the desired cross section, and cooled.

Circulating air ovens are best suited for these heating operations. Infra-red lamps can also be used with the material held approximately 16 in from the lamp faces to obtain even heat distribution.

Welding. Welding of rigid vinyl is similar to welding metals; practically any assembly can be made.

Hot air, at about 375 to 390 F, is used to soften the rigid vinyl welding

rod and the material being welded. A special welding gun is used, with either a gas or electric resistance heater. The hot air is supplied at an output flow of 35 to 50 cu. ft. per hour.

Machining. In machining, precautions must be taken to prevent overheating because of the material's thermoplasticity. Good results are dependent upon proper control of tool design, tool sharpness, casting speed and rate of feed.

Drilling can be done with standard drills and normal feeds if holes are not too deep. Where the hole depth is over twice the diameter the drills should have extra large flutes and should be ground to reduce end resistance. The area of cutting surface should be about one-third of normal.

For turning, facing, boring and chasing operations ordinary metal cutting tools should be modified by increasing front and side clearances to reduce heat formation and facilitate chip removal.

For milling, spiral cutters are best. Higher milling speeds can be obtained by providing extra clearance.

Applications

The outstanding corrosion resistance of rigid vinyl makes it suitable for applications such as valves, tanks, ducts, piping, fans and other equipment handling corrosive liquids or gases. It has replaced stainless steel and lead for many such applications.

Piping extruded from rigid vinyl, Fig 5, has the desirable combination of good strength and light weight. A 1¼ inch Geon 404 pipe with a specific gravity of only 1.35 to 1.45, has a tensile strength of 8600 psi and requires 2000 psi to break it.

Other applications that take advantage of the strength-weight properties as well as colorability of this material are instrument, typewritten and business machine cases, luggage, and tote boxes. Corrugated sheet of various colors is suitable for many structural purposes.

Electrical applications include:

1. Weatherproof linewire for which its good deformation and abrasion resistance, good low temperature properties and high dielectric strength are advantageous.

2. Primary insulation for military field wire and aircraft wiring. No jacketing materials are needed to impart abrasion or deformation resistance.

3. Primary insulation requiring high electrical properties, such as television lead-in wire, communication and signal wire. The plasticized material is not suitable for these applications.

4. Applications requiring compositions that do not contaminate the primary insulation, such as coaxial cable jackets.

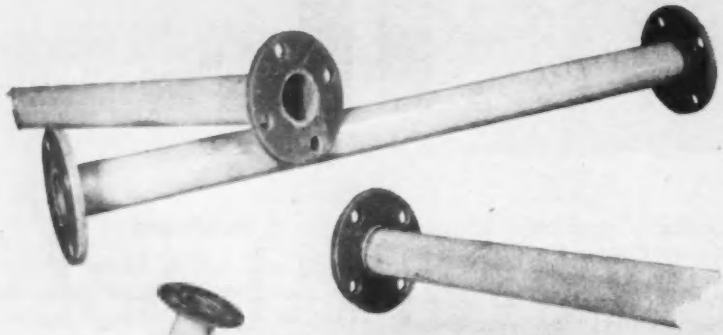


Fig. 5—Fabrication of rigid vinyl piping is simplified by its ease of cutting and its weldability. The above rigid vinyl piping was welded to flanges of the same material.

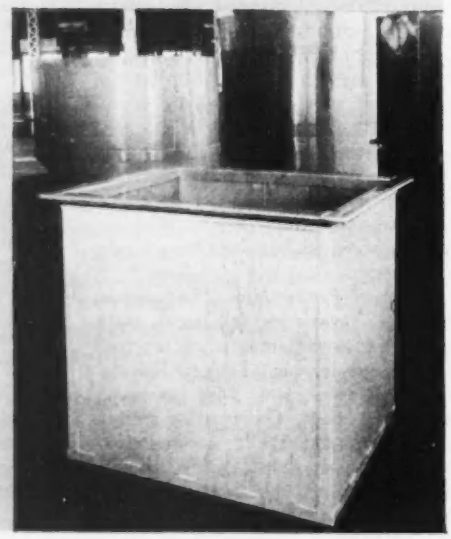


Fig. 6—Tanks fabricated from rigid vinyl can be used alone or as liners in steel tanks as shown above.

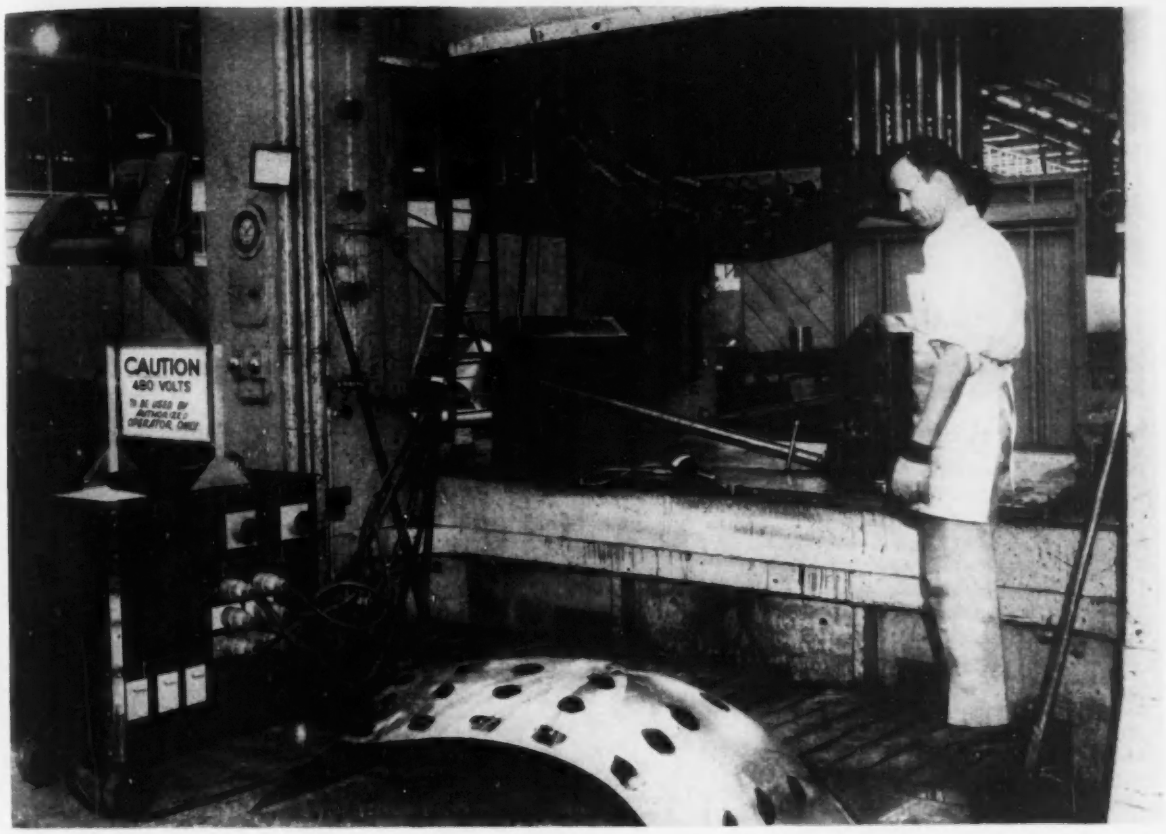
Lucoflex Div., Van Dorn Iron Works

Table I—Average Properties of Lucoflex

Specific Gravity	1.4
Tensile Strength, psi	8,600
Modulus of Elasticity in Tension, psi, x 10^5	3.5
Elongation, percent	6.2
Compressive Strength, psi	11,000
Modulus of Elasticity in Compression, psi x 10^5	3.5
Flexural Strength, psi	13,200
Modulus of Elasticity in Flexure, psi x 10^5	3.5
Hardness—Rockwell	R-121
Hardness—Rockwell, Pen/Recovery	89/75
Hardness—Scleroscope	65
Hardness—Durometer D	86
Heat Distortion F	177
Flame Resistance	Self-extinguishing
Linear Expansion Coefficient x 10^{-5} per deg C	6
Linear Expansion Coefficient x 10^{-5} per deg F	3.3–4.5
Specific Heat	0.32
Thermal Conductivity 10^{-4} Btu/hr/ft²/deg F/in	2.8
Char Temperature	430 F

Table II—Electrical Properties of Wire Insulation

Insulation Properties	Plasticized Vinyl (Standard Wire Insulation)	Rigid Vinyl (Geon 404)
Insulation Resistance megohms—1000 ft 50 C—1/32 in wall	50–100	20,000 35,000
Dielectric Strength (v/mil) 25 C in water 1/64 in Wall	700–900	1,200–1,300
1/32 in wall	600–800	800–1,000
Power Factor 1,000 cycles 25 C	0.07–0.09	0.015–0.02
Dielectric Constant 1,000 cycles 25 C	5–7	3.0–3.2
Loss Factor 1,000 cycles 25 C	0.35–0.6	0.045–0.064
Power Factor 1,000 cycles 50 C	0.09–0.11	0.012–0.017
Dielectric Constant 1,000 cycles 50 C	6–8	3.2–3.4
Loss Factor 1,000 cycles 50 C	0.54–0.88	0.038–0.058



HOT FORMING of double curvature of a P2V Navy patrol bomber cowl skin on a 1,500 ton capacity Clearing double action press.

Hot Forming Aluminum Alloys

The need for hot forming of high strength aluminum alloys; its effects on formability and physical properties; selection of heating procedure.

M. P. MEINEL
Lockheed Aircraft Corp.

TO INCREASE DESIGN EFFICIENCY there has been a constant demand for materials possessing improved metallurgical characteristics and higher strengths. The new alloys and materials to meet this demand are usually developed at the expense of formability. This is particularly true in the case of new aluminum alloys used for modern high-speed aircraft. Some of these developments pose a severe penalty on the versatility of design in that they increase product cost and create production difficulties.

Yield strength and elongation are the two most widely recognized gages for formability, and when in the combination of high yield and low elongation, they give a fairly reliable prediction that poor forming characteristics can be anticipated. High yield strength of a material, while ideal for the design engineer to reduce weight and permit compact structural designs, is usually accompanied by low elongation. Tooling is required to be more complex to generate the necessary forming stresses.

The present basic trend in aircraft design of reducing the number of detail parts for a given unit and increasing the complexity of the remaining parts is one that demands high ductility in a material and is fundamentally in conflict with results in the development of higher strength materials. This situation is responsible for the production problems that have arisen with new metals such as 75S aluminum alloy, heat treatable stainless steel and titanium alloys.

Formability is increased through the application of heat. The resultant increased elongation and lower yield strength reduce the forming pressures required to produce deformation and increase the total amount of deformation that can take place before fracture.

Hot forming is adaptable to annealed material. Many of the limitations applying to heat-treated stock can be disregarded. Loss of strength and corrosion resistance are of no concern since the parts must be heat-treated after hot forming is complete. The greatest gain in formability is obtained with annealed material formed at 450 F to 500 F, developing measured elongation as high as 90 percent in

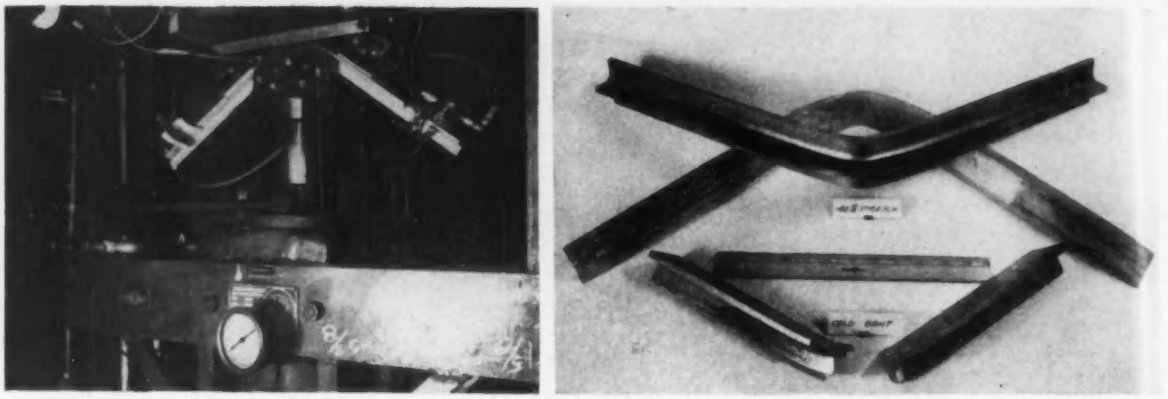


Fig. 1—Resistance heating is ideally suited for applications such as extrusions, bar and strip where bends are to be made in one or more localized areas. It allows the part to be heated, while it is being formed. The 75ST extrusion tested as at left showed a 166 percent increase in formability at 250 to 300 F over the cold bent specimen. No loss in strength occurred during bending.

extreme cases. It is possible therefore to accomplish in one operation the fabrication of a severely contoured part that would require several forming stages if done at room temperature.

The improved ductility is advantageous from a design standpoint; new concepts of design become possible; parts can be larger; material thicker and draws deeper. Flanging operations can reach unprecedented complexity. While much testing remains to be done to reveal the complete significance of this phase of metal working, the results to date justify high hopes for remarkable design improvements. The following preliminary values indicate the effect of hot forming on a typical aluminum alloy:

Bending of Sections—30 percent elongation at 300 F (75ST extrusion)

Stretch Forming—35-50 percent elongation at 450 F (24 SO and 75 SO sheet)

Bend Radii—$\frac{1}{2}$ that of room temperature values (See Table I)

Deep Drawing is substantially improved at elevated temperatures to the extent of nearly doubling the maximum depth to which a regular cap may be drawn in a single operation.

Consideration must be given to the distribution of elongation at various temperatures and alloy tempers. The most uniform distribution for aluminum alloys occurs at room temperature in the heat-treated tempers. This uniformity decreases as the temperature exceeds 250 F until at 500 F, elongation becomes highly localized, resulting in failure due to necking rather than tensile fracture. To overcome this disadvantage it is necessary to develop a fabrication procedure that will minimize or counteract the necking tendency and consequently give more even elongation distribution.

Effect of Heat on Physical Properties

At temperatures of 500 F and higher, the properties of all common structural aluminum alloys become similar and the selection of an alloy is not particularly important except as it pertains to final room temperature properties. Parts formed at these heats require solution heat-treatment after forming. At lower temperatures up to 300 F, however, the change brought about by the applied heat, Fig. 1, differs considerably according to the chemical composition of the material. Alloy 24ST exhibits a slow response to the rise in temperature up to the point where its heat-treated properties become permanently affected. This reaction makes 24ST a poor material to use for hot forming if the temper properties are to be retained after forming. In contrast, 14ST and 75ST, with strength superior to 24S, show a rapid drop in yield strength so that at 300 F they are relatively close to the 24ST value. Therefore the high yield, undesirable from a forming standpoint, can be temporarily eliminated by the application of heat at 300 F but it will return to its original value after cooling back to room temperature.

A phenomenal increase in elongation, Fig. 1, for 75ST occurs at temperatures of 300 to 400 F where elongation is high enough to meet extreme formability requirements. Under these conditions 75ST becomes amenable to difficult parts that would tax a ductile alloy at room temperature.

When forming is attempted on heat-treated material it is necessary to carefully control the conditions under which hot forming is accomplished if the desired strength level is to be maintained. Holding the material excessively long at temperature will result in a permanent loss in yield and tensile strength, the amount being in proportion to the time interval in excess of the safe working period. A typical representation of time and temperature is shown in Fig. 2. A radical loss occurs when temperatures pass 400 F and are held for more than one or two minutes. At 600 F or

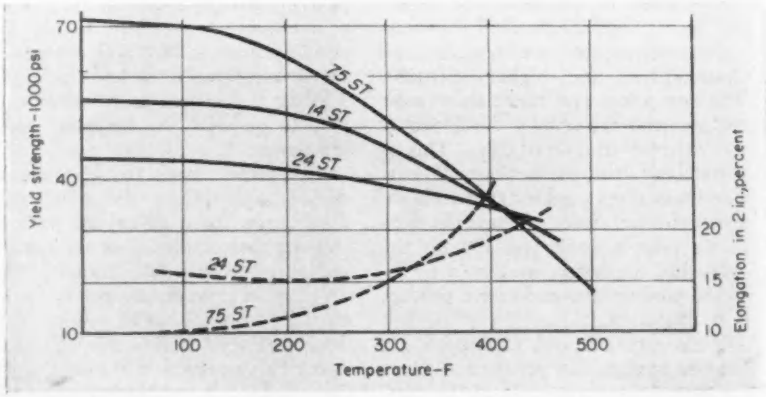


Fig. 2—Effect of temperature on yield strength of aluminum alloys.

higher, the loss will be instantaneous in most cases. Aluminum alloys subject to hot forming while in the solution heat-treated condition should be precipitation heat-treated (aged) to restore the original corrosion resistance.

Heating Practices

Two heating practices for forming aluminum alloys are in use today: (1) application of heat directly to the part or; (2) to the tools which then heat the part by conduction. For applications requiring high production, these two practices can be combined to secure maximum efficiency.

Heating of parts or blanks can be accomplished in several ways.

(1) Soaking in circulating hot air oven
(2) Immersion in hot oil
(3) Radiant heating elements
(4) Resistance heating
(5) Contact with heated dies
(6) Infra-red lamps

Induction heating and techniques where an open flame impinges on the part or blank are generally considered as unsatisfactory because of their adverse effect on the properties of the aluminum alloy.

If the forming operation is instantaneous and the area of contact between the blank and tool is small, it is usually satisfactory to merely use a heated blank on cold tooling. To prevent heat loss in more lengthy forming operations, both the die and blank should be heated.

Resistance heating is best adapted to long narrow parts. Inasmuch as it is possible to heat as the part is being formed, resistance heating is particularly well suited to hot forming operation which require 20 min to ½ hr to complete.

The use of hot air ovens is slow in regard to rate of heat transfer but works out well if parts can be heated in batches. If each hot part is replaced by a cold part, it is often possible to conduct forming operation with no delay waiting for parts to heat up. Accurate control of temperature is readily accomplished by the use of good controllers.

Radiant heating is ideal in many respects since it has a better rate of heat transfer than hot air, is clean and compact and does not require a large outlay of equipment. Because of their size and light weight, radiant heating elements are suited for portable setups or where heat is to be maintained on a part during the forming sequence.

While hot oil heating is very rapid, it is limited as to maximum temperature and is rather messy because of the accumulation of excess oil on the dies and machinery. It is also more easy for workers to become burned due to hot oil dripping on hands or arms.

Influencing Factors. Several influencing factors must be considered before a specific plan of hot forming can be established for a given part. Most important of these is the alloy to be formed since the response to heat varies greatly, particularly in the aluminum alloys. It is desirable to maintain the lowest possible forming temperature, the alloy then being selected with this factor in mind.

The manner of heating should be determined on the basis of rate of heat transfer, convenience of handling and use of equipment, quantity of parts to be made, and the avoidance of undesirable metallurgical characteristics such as stress or intergranular corrosion or loss of strength.

The optimum temperature is determined by material in use and the amount of ductility that is desired during the forming operation. If the material is to be worked in the strongest temper, the use of excessive temperatures will result in permanent lowering of strength, even though held for only a few minutes duration. This can occur in certain aluminum alloys at temperatures as low as 350 F.

The total time at temperature is not only a major factor in determining the maximum safe temperature that can be used but it can also be the direct cause of a permanent loss in properties if the heating cycle is excessively prolonged.

To avoid the aggravating problem of heat-treat distortion of aluminum alloys, greater use will undoubtedly be made of hot forming of fully heat-treated stock, the heat being used to create the needed ductility for normal forming operations.

Table I—Effect of Heat on Bend Radii of Aluminum Alloys

Alloy	75 F	300 F	Bend Radius*		Reduction, percent	
			400 F	550 F	300 F	550 F
61ST	0.16	0.12	#	#	20	#
24ST	0.31	0.31	#	#	0	#
75ST	0.44	0.22	#	#	50	#
24SO	0.12	0.09	.06	.04	25	67
75SO	0.12	0.09	.06	.04	25	67

* Based on .080 Material
\# Forming at these Temperatures Causes Permanent Loss of Strength

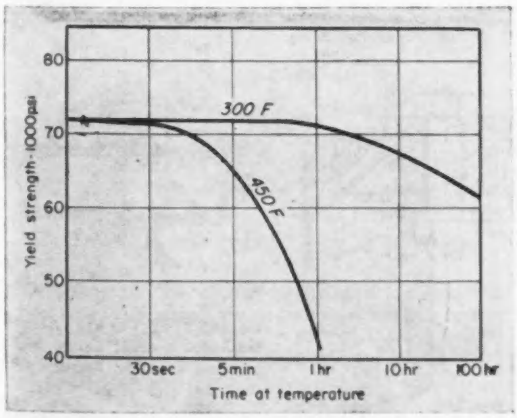


Fig. 3—Effect of heating time on 75ST.

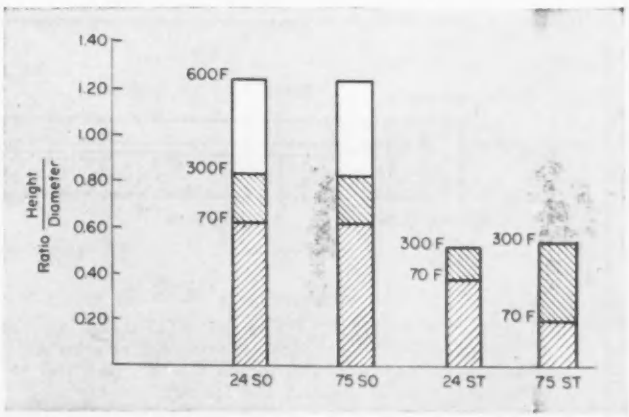


Fig. 4—Effect of temperature on deep drawing of aluminum alloys.

Methods of Attaching Glass to

GENERAL RECOMMENDATIONS

1. Design the glass for compression loads whenever possible.

2. Load the glass uniformly. Avoid concentrated or point loads, by gasketing.

3. Design mounting to compensate for differential expansions. Glass have an expansion range from $1.8-5.0\times10^{-6}$ in/deg F.

4. Glass under load should be clamped in a rigid fixture that will not deform when load is applied.

5. Glass not under load can be mounted in a flexible support so that loads on the structure are not transmitted to the glass.

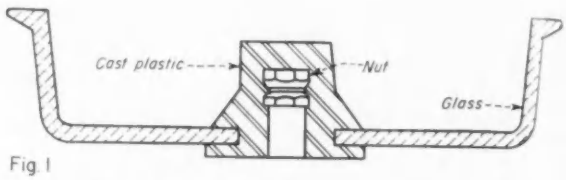


Fig. 1

CAST PLASTIC JOINT. Glass part is attached to threaded metal insert by cast plastic hub. For moderate loads.

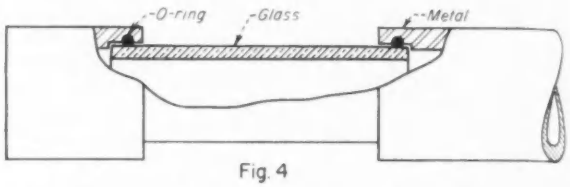


Fig. 4

O-RINGS SEAL glass tubing to metal fixture. Shoulders in the metal tubes retain the glass member in its proper place.

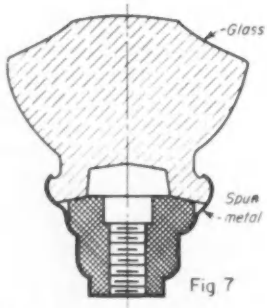


Fig. 7

SPUN METAL JOINT. For light loads, a thin metal sheet can be spun around a glass shoulder to form an attachment as illustrated above.

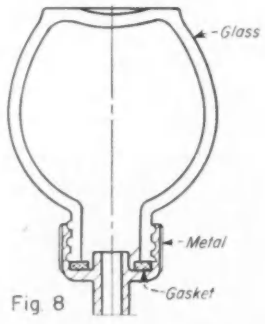


Fig. 8

THREADER JOINT. For low pressure applications threaded glass container can be screwed into metal fixture. Cement can also be added.

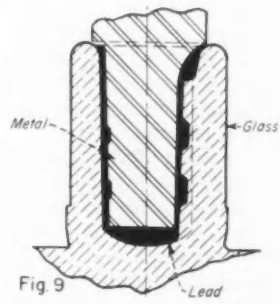


Fig. 9

PERMANENT SEAL. Poured lead locks metal arbor to hubbed glass part. Use is restricted, however, to moderate loads and temperatures.

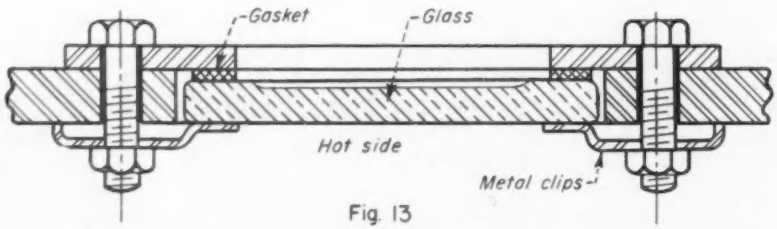


Fig. 13

FURNACE SIGHT GLASS. Small metal spring clips hold glass in place and allow for different rates of expansion of glass and metal fixture. This method of suspension also insures that the glass will be heated uniformly, reducing thermal gradients and internal stresses.

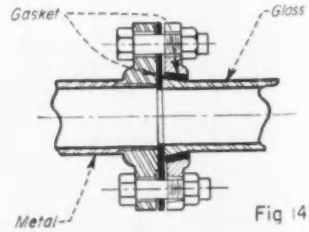


Fig. 14

GLASS PIPE TO METAL PIPE. Gasketed conical flange reduces bending stresses. Rubber gasket seals flat end of glass pipe.

to Metal Structures

M. H. HUNT
Corning Glass Works

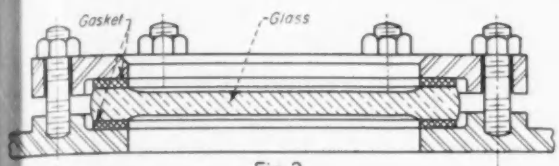


Fig. 2

PRESSURE-TIGHT JOINT. Glass sheet is clamped uniformly in compression using rubber or asbestos gaskets.

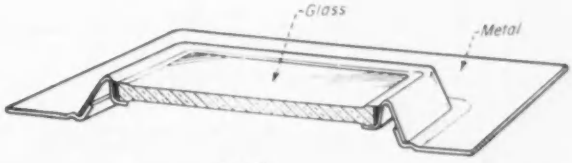


Fig. 3

SOLDERED JOINT. Glass has metallized edge for soldering. Frame is semi-rigid to allow for differential expansion.

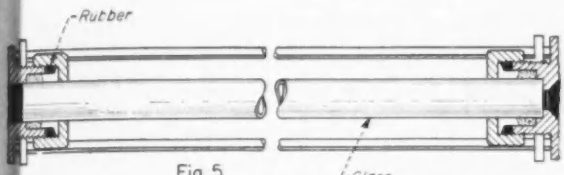


Fig. 5

TUBULAR GAGE GLASS is attached to liquid level fixture. Rubber gasket is compressed to effect a leak-proof seal.

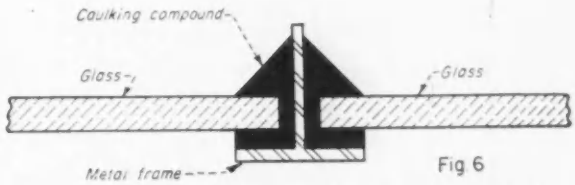


Fig. 6

WINDOW JOINT. Resilient caulking compounds and rubber cement make liquid-tight seals with metal frames.

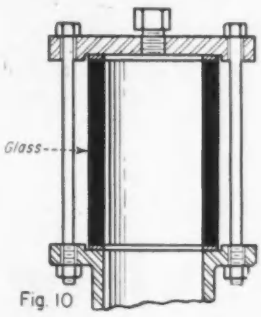


Fig. 10

GLASS TUBE IN PRESSURIZED OIL SYSTEM. Glass is clamped in compression; resilient gaskets are added to help distribute load uniformly.

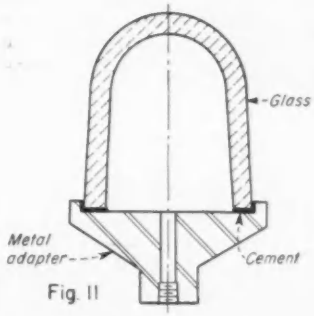


Fig. 11

CEMENTED JOINT. Container shown carries explosive in oil wells. High external pressure keeps cemented joint in compression to maintain the seal.

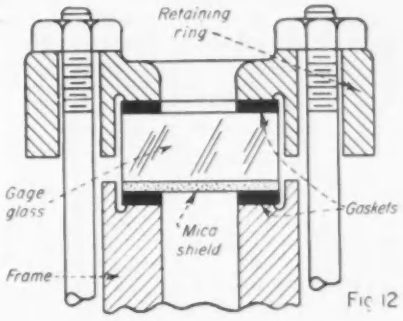
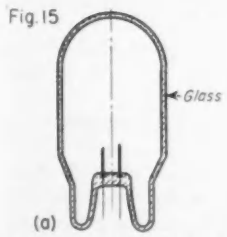
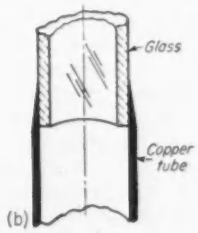
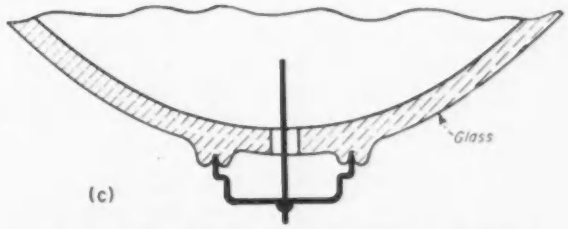


Fig. 12

GAGE GLASS attached to water level column on a steam boiler. The mica shield protects the glass from corrosion by the alkaline boiler water.







ELECTRICAL CONNECTIONS. (a) Inside of vacuum tubes. First, wire is sealed to tubular glass flare by pressing the hot glass around the wire. The flare and wire assembly is then sealed to the tube body. Dumet (42 per-cent nickel iron coated with copper) is commonly sealed to high expansion glasses. Tungsten and Kovar are sealed to low expansion glasses. (b) Inside of air and water cooled transmitting tubes. Thin copper tube sealed to glass tubing is thin enough to compensate for different expansion coefficients (c) Inside of glass sealed-beam headlight. Thin 42% nickel iron metal cup is sealed directly to glass. Kovar or similar metals can also be used. Flexible cup does not stress the glass.

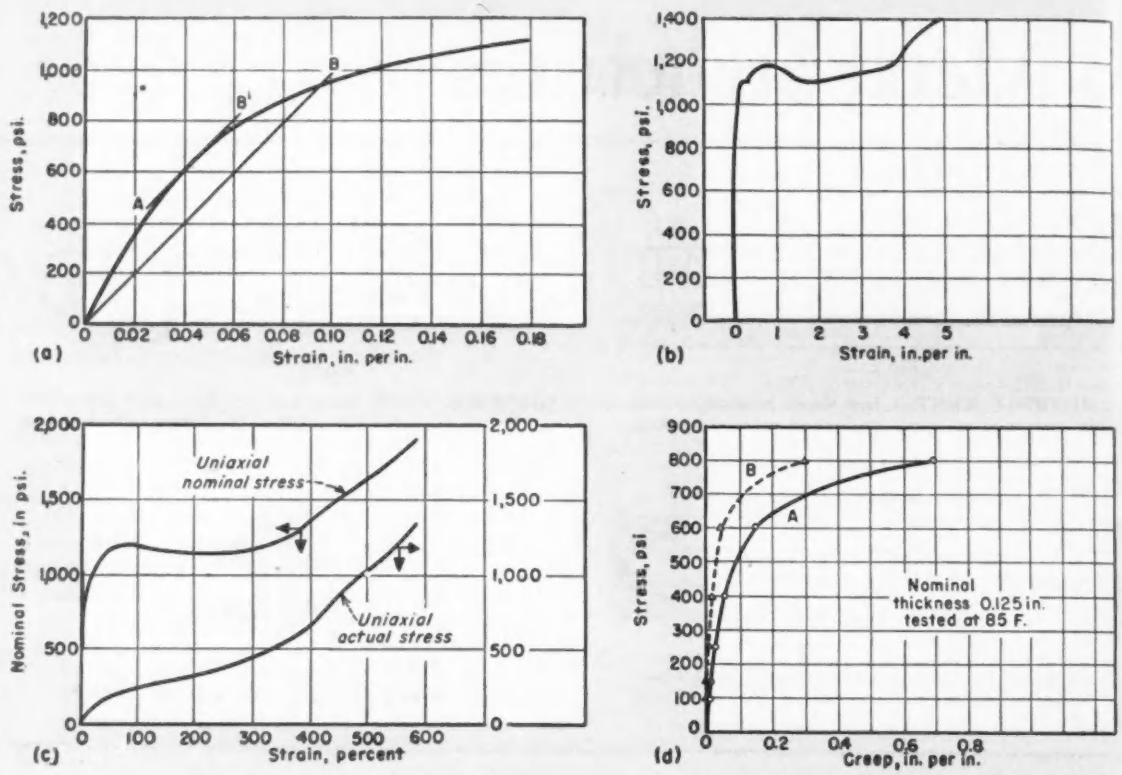


Fig. 1—(a) Stress-strain curve for polyethylene at low straining rate and high magnification. (b) Stress-strain curve at high straining rate and low magnification. (c) Nominal stress-strain and actual stress-strain curves for polyethylene. (d) Relations between stress, permanent and total strain of polyethylene after long time loading. Curve A shows total strain after 10,750 hr creep; curve B indicates the permanent deformation remaining after 10,750 hr creep followed by 600 hours with no load.

Engineering Potential of Polyethylene

HENRY LEE*

POLYETHYLENE is a tough, semi-flexible impact resistant plastic. Its potential as an engineering material is widespread because:

1. It has a high softening point and good mechanical properties over a wide range of temperatures.
2. It possesses superior electrical insulating properties.
3. It exhibits outstanding resistance to virtually all chemicals.
4. It can be readily fabricated into essentially any shape.

In chemical composition polyethylene is similar to high melting paraffin waxes—hence its unique chemical and electrical properties. Its crystalline structure and consequently its mechanical properties differ considerably from the waxes. It is semi-crystalline, semi-amorphous in structure and many of its mechanical properties are analogous to those of micro-crystalline, non-ferrous metals such as lead, copper or brass. It also has some characteristics of the amorphous plastics.

* Formerly with Bakelite Co.

Mechanical Properties

Mechanically, polyethylene is a visco-elastic material—i.e. strain is not directly proportional to stress but rather to both stress and the length of time of the application of the stress. The influencing factor of time is common to many materials especially at elevated temperatures.

In a typical visco-elastic material there are three components to the strain or deformation induced by stresses:

1. A completely recoverable elastic component.
2. A delayed or retarded elastic component most of which is recoverable.
3. An irrecoverable viscous component.

The relative magnitudes of these components vary with the specific material, temperature, and magnitude of the load.

For polyethylene, at temperatures below its softening point of 110 C, the elastic and delayed elastic types of deformation are predominant. Viscous or ductile types of deformation are small unless the material is first

Table I—Commercially Available Polyethylene Resins

Designation	Supplier	Weight Average Molecular Weight	Parallel Plate Plastometer Grade Numbers *	Remarks
DYGT	1	7,000	—	Used in hot melt coatings and wax modification and upgrading.
DYJT	1	10,000	—	Used in hot melt coatings and wax modification and upgrading.
DYLT	1	12,000	—	Used in hot melt coatings and wax modification and upgrading.
DYNF	1	18–19,000	45	Used in unmodified form or in compounds for general purpose molding and extrusion and electrical extrusion. Also in hot melt coatings and wax modification and upgrading.
DYNH	1	20–22,000	55	Used in unmodified form or in compounds for general purpose molding and extrusion and electrical extrusion. Also used in hot melt coatings, wax modification, hot solution and extrusion coatings.
DYNJ	1	22–24,000	65	Used in unmodified form or in compounds for general purpose molding and extrusion and electrical extrusion. Also used in hot melt coatings, wax modification, hot solution and extrusion coatings.
PM-1	2	18–19,000	—	Used in unmodified form or in compounds for general purpose molding and extrusion and electrical extrusion.
ALATHON A (PM-1)	2	18–19,000	50	Hot melt and solution coatings.
ALATHON B	2	16–17,000	—	Hot melt and solution coatings.
ALATHON C	2	12–13,000	—	Hot melt and solution coatings.
ALATHON D	2	8–9,000	—	Hot melt and solution coatings.

1. Bakelite Division, Union Carbide and Carbon Corporation. 2. E. I. du Pont de Nemours and Co., Inc.
* A test measuring resistance to flow at elevated temperatures which may be correlated to molecular weight. The higher the molecular weight of a resin, the greater is the resistance to flow, reported as the parallel plate plastometer grade number.

Polyethylene is unique among the plastics because it has the chemical and electrical properties of high melting point waxes and mechanical properties analogous to both crystalline non-ferrous metals and amorphous plastics

strained excessively. Above the softening point the viscous component becomes predominant and the elastic components gradually disappear and thus allow the material to be fabricated by molding, extruding and other techniques.

A typical stress-strain curve for polyethylene, at low rates of straining and with high magnification of the coordinates, Fig. 1(a), shows the influence of a large delayed elastic component. It resembles the logarithmic curve common to crystalline, non-ferrous metals—i.e. strain is not directly proportional to stress. The absence of a definite elastic portion under such test conditions suggests an apparent modulus of elasticity for use in design.

At high rates of straining, and low magnification, Fig. 1(b), polyethylene resembles ferrous metals and various synthetic plastics. The curve has a linear pseudo-elastic section, a "knee" or inflection point at which neck-down occurs, and a cold drawing portion.

Polyethylene will recover within a short time from elastic and delayed type deformations, but strains imposed after "neck down" are definitely cold drawing and not elastic elongation. The extent of the necking-down and cold drawing that is required to allow the crystals to move and orient is revealed by data, Fig. 1(c), in which the nominal stress (tensile force divided by original cross-sectional area of specimen) is compared with the actual stress or tensile force divided by the actual cross-sectional area of the necked-down specimen. A marked difference is noted between nominal and actual tensile stresses because of the large "neck-down" of the specimen.

This behavior of polyethylene can be attributed to its crystalline structure and described qualitatively in terms of the orientation of crystals that occurs when it is stressed beyond its apparent elastic limit. Polyethylene is partly crystalline in structure, 55 to 73 percent of it being present as small oriented crystalline aggregates called "crystallites." The remainder of the material surrounding the crystallites is amorphous, i.e. without definite alignment or configuration.

Stiffness. Polyethylene's stiffness or apparent Young's modulus is midway

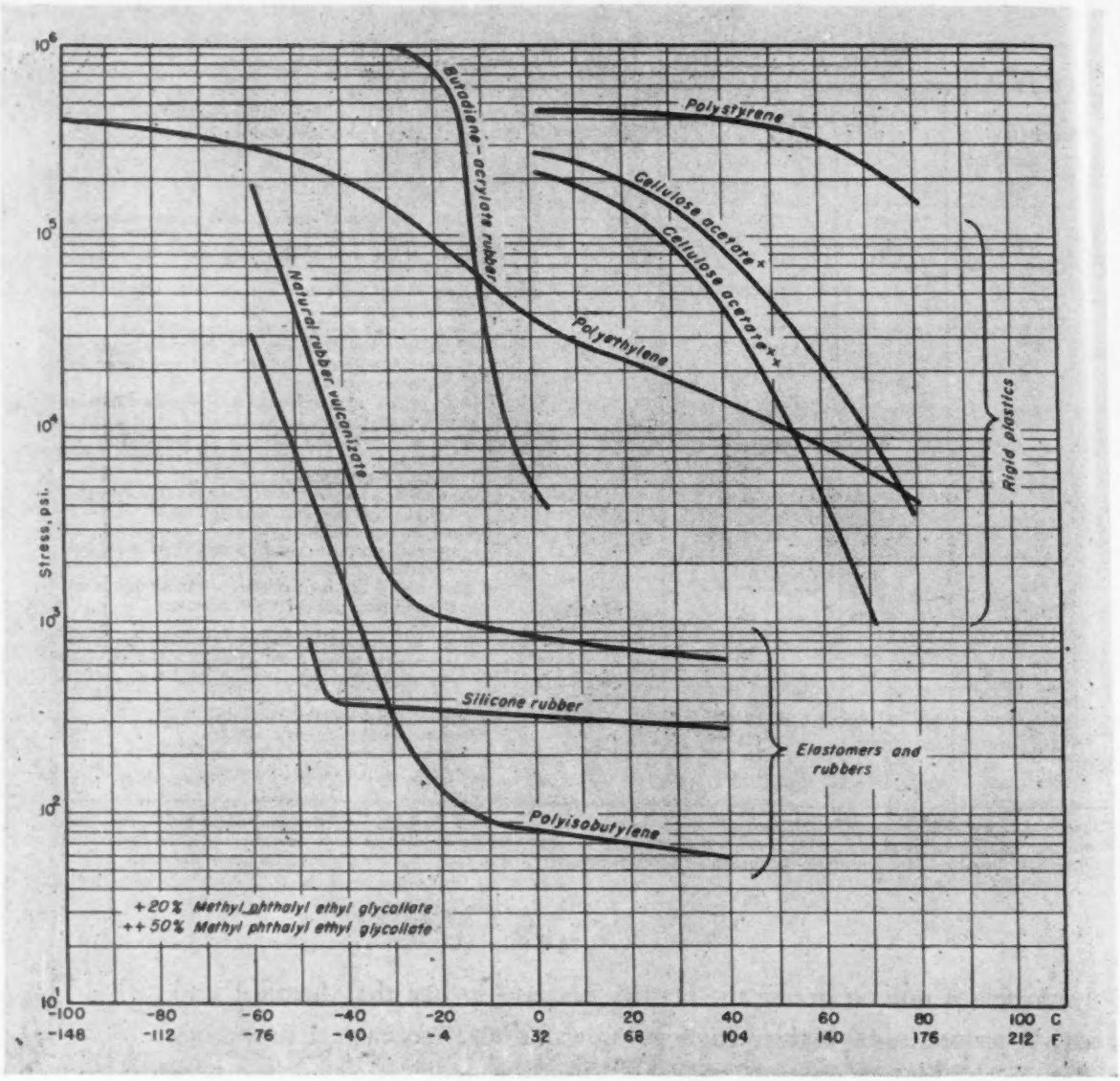


Fig. 2—Good retention of flexibility of polyethylene with decreasing temperatures is evident when stiffness-temperature characteristics are compared to those of several elastomers and rubbers as well as to those of other rigid plastics.

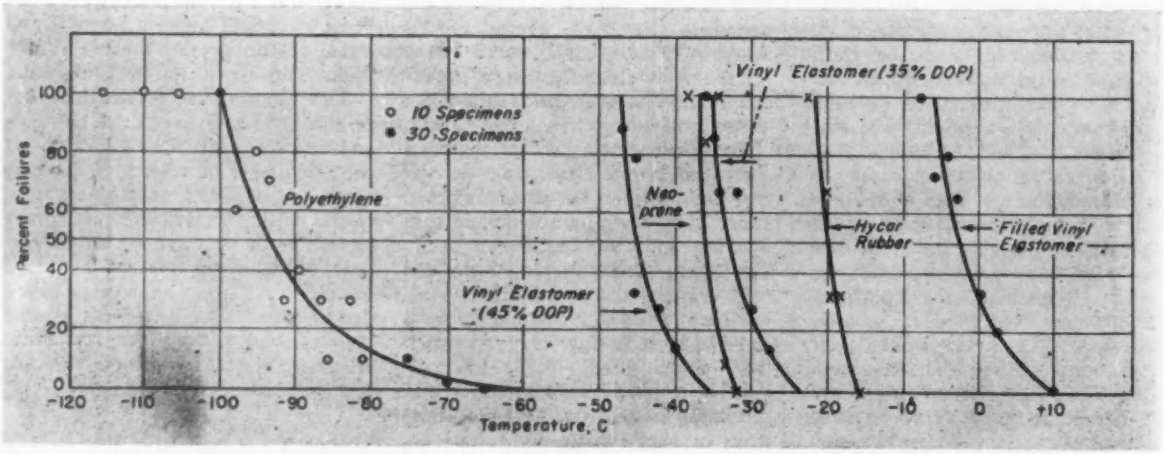


Fig. 3—Comparison of brittle temperature failures of polyethylene with those of various plastics, elastomers, and rubbers

between rigid and flexible materials. In thin sections and in film and sheeting it is quite flexible. In thick sections it feels stiff and hard.

Elastic Limit. For most engineering work, the apparent linear elastic portion is of chief concern since it is seldom desirable to design with the intent of straining the material beyond the elastic limit. It is generally recommended that, although polyethylene will recover from strains approaching one hundred percent, the point of four percent strains should be considered as the elastic limit for uniaxial tensile stressing. Stresses in excess of four percent induce creep in increasingly greater amounts. However, a considerable percentage of strains induced beyond the elastic limit will be recovered if the material is given sufficient time to relax.

Creep. At normal temperatures and at stresses below the yield stress, the viscous or cold flow component for polyethylene is very small. Above the elastic limit the creep component becomes increasingly larger with increase in stress. However, this creep, at stresses of engineering interest for such applications as cable sheathing (below 400 psi), is comparable to lead and its alloys, and only realized after substantial initial elongation. Such a relatively large initial elongation for a given stress is to be expected since polyethylene is much less stiff than lead, having a modulous of elasticity 2×10^4 psi as compared to 2×10^5 psi for lead. In addition, even after 20,000 hours of continuously applied load, a constant creep rate has not been obtained, Fig. 1 (d), although the tangent creep rate indicates that there is only a slight change in rate after approximately 10,000 hours of continuous loading. Lead sheathing alloys, on the other hand, usually show a steady creep stage after only a few thousand hours under sustained load. The initial elongation of polyethylene is recoverable upon the release of the load.

Thus, in structures such as cables, where creep is expected to be encountered because of prolonged steady stressing, the design must permit freedom for the development of an initial strain.

Polyethylene is not difficult to handle in this respect. Coils of No. 6 polyethylene line wire weighing one hundred fifty pounds have been stacked six high and stored for one year in a circulating air oven at 50 to 60 C. with no visible resultant deformation even on the bottom coils. In the application of line wire, polyethylene jacketed soft copper ties, when properly applied, inhibit any possible cold flow at insulators.

Even above the softening point polyethylene retains some degree of toughness until the elastic and delayed elastic components completely disappear.

Coldwork and Heat Treatment. As the temperature of polyethylene is raised, the crystallites begin to disappear and a gradual transition to the amorphous state takes place. At about 110 C the transformation is complete and all of the polyethylene is amorphous. Shock cooling or quenching amorphous polyethylene inhibits the rate of formation and size of its crystallities and to some extent alters its physical properties. The tensile strength of an annealed specimen is greater than that of a quenched specimen. On the other hand, because of its higher amorphous content, a quenched part evidences better resistance to biaxial stress failure.

Cold drawing of polyethylene is possible because of the presence of a crystalline phase. The crystallites in monofilaments can be oriented by cold drawing and the ultimate tensile strength increased from about 2,000 to about 25,000 psi. If an oriented, cold-drawn monofilament is heated while free to relax, considerable recovery results. Heating the monofilament while under controlled tension, however, produces a highly oriented monofilament with high tensile strength.

Low Temperature Properties. The stiffness of polyethylene, Fig. 2, is less sensitive to changes in temperature than many plastics and rubbers. This good retention of flexibility with decreasing temperatures partly explains its excellent rating on low temperature impact brittleness tests. Fig. 3 shows the temperatures at which given percentages of samples of various plastic and rubber materials fail under low temperature impact. Polyethylene ranges from —65 down to —100 C as contrasted with the —10 to —50 C range for the other materials.

Electrical Properties

Combining strength and toughness with a non-polar molecular structure, polyethylene has a very high resistivity, a high dielectric strength, a very low power factor and a low dielectric constant.

The resistivity of polyethylene (over

Table II—Dielectric Strength of Polyethylene for Various Thicknesses and Temperatures

Thickness of Sheet, Mils	Volts Per Mil	
	30 C.	90 C.
10	1,700	1,300
20	1,200	1,050
40	900	850
60	750	700
80	600	550

Table III—Dielectric Properties of Low-Loss Plastics[a]

Material	Dielectric constant[b]				Dissipation factor[b]				Water absorption per cent (24-hr ASTM)[c]
	60 cps	10^3	10^6	10^8	60 cps	10^3	10^6	10^8	
Thermoplastic									
Polyethylene	2.3	2.3	2.3	2.3	0.0005	0.0005	0.0005	0.0005	0.01
Polytetrafluoroethylene	2.0	2.0	2.0	2.0	0.0005	0.0005	0.0005	0.0005	0.01
Polystyrene	2.5–2.6	2.5–2.6	2.5–2.6	—	0.0001–0.0003	0.0001–0.0003	0.0001–0.0003	—	0.05
Poly-monochlortrifluorethylene	2.9	2.8	2.5	2.5	0.005	0.025	0.009	0.005	0.01
Thermosetting									
Mica-filled molded phenolics[d] #1	5.4	5.1	4.9	—	0.020	0.015	0.008	—	0.05
#2	4.5	4.5	4.3	4.3	—	0.016	0.006	0.012	
Mica-filled molded alkyd	6.2	—	4.9	—	0.054	—	0.018	—	0.15
Unfilled polyester resin	3.12	—	3.00	2.78	0.0039	—	0.010	0.004	0.24

[a] All at room temperature. [b] ASTM (D150–47T). [c] ASTM (D570–47). [d] Two competitive makes of low-loss phenolic.

10^{16} megohm-cm) is too high to be measured accurately by conventional insulation test methods. The dielectric strength, Table II, is over 1000 for a 20 mil specimen at room temperature. The power factor of unmodified polyethylene is only 0.0005 at 50 megacycles and 25 C. Modification of polyethylene with two per cent carbon black pigments raises the power factor to 0.0044 at 50 megacycles and 25 C. The variation of power factor with frequencies ranging from 10 to 10^{10} cycles per second is negligible. At 25 deg. C, the dielectric constant of unmodified polyethylene is only 2.35 over a wide range of frequencies. Addition of two percent carbon black produces no change of the dielectric constant. The relationship of polyethylene to other low loss plastics is reported in Table III.

The low power factor and low attenuation (loss in amplitude of very high frequency signals) of polyethylene, account for its widespread use in high frequency systems such as radar, co-axial cables, and antenna lead-in wires for television installations.

Water has little effect on the electrical properties of polyethylene. The power factor and the dielectric constant remain essentially constant for frequencies ranging from 60 cycles to 5 x 10^7 cycles despite immersion in water for long periods.

The retention of these excellent electrical properties qualify polyethylene for use in line wire, drop wire, and in cables for railway signal systems, telephone and telegraph communication systems and many other applications.

The high dielectric strength and resistivity of polyethylene allows its use in various high voltage wires and cables. In addition, its low water absorption and general toughness and chemical inertness promote its use in submarine cables, Fig. 6(a), and in power cables in chemical plants. The maximum operating temperature of polyethylene on electric cables is generally held to be 90 C.

Other applications utilizing the electrical insulating advantages of polyethylene include circular television tube protector rings, radio tube sockets that can be mounted in a chassis with only a light blow from a hammer, and the insulating jacket, Fig. 6(b), on the potential coil of a watt-hour meter.

Fig. 4—Wrench set case molded of polyethylene is sturdy, attractive and durable.

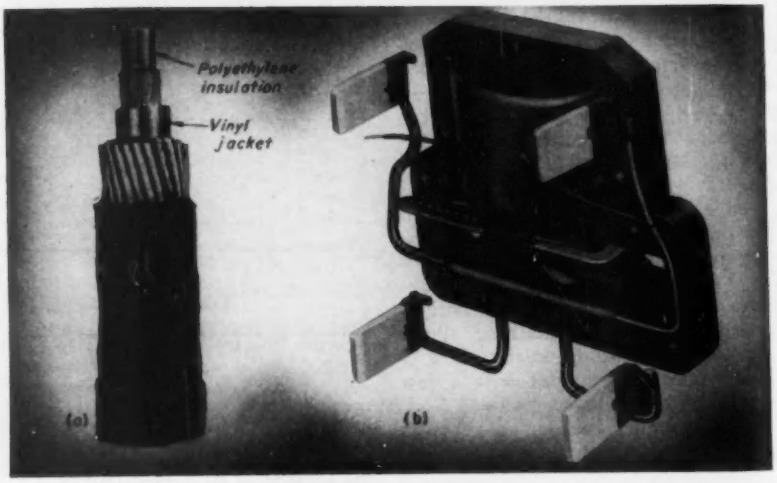


Fig. 6—(a) Submarine cable jackets of polyethylene have excellent corrosion resistance, high strength and light weight, as well as good electrical properties.

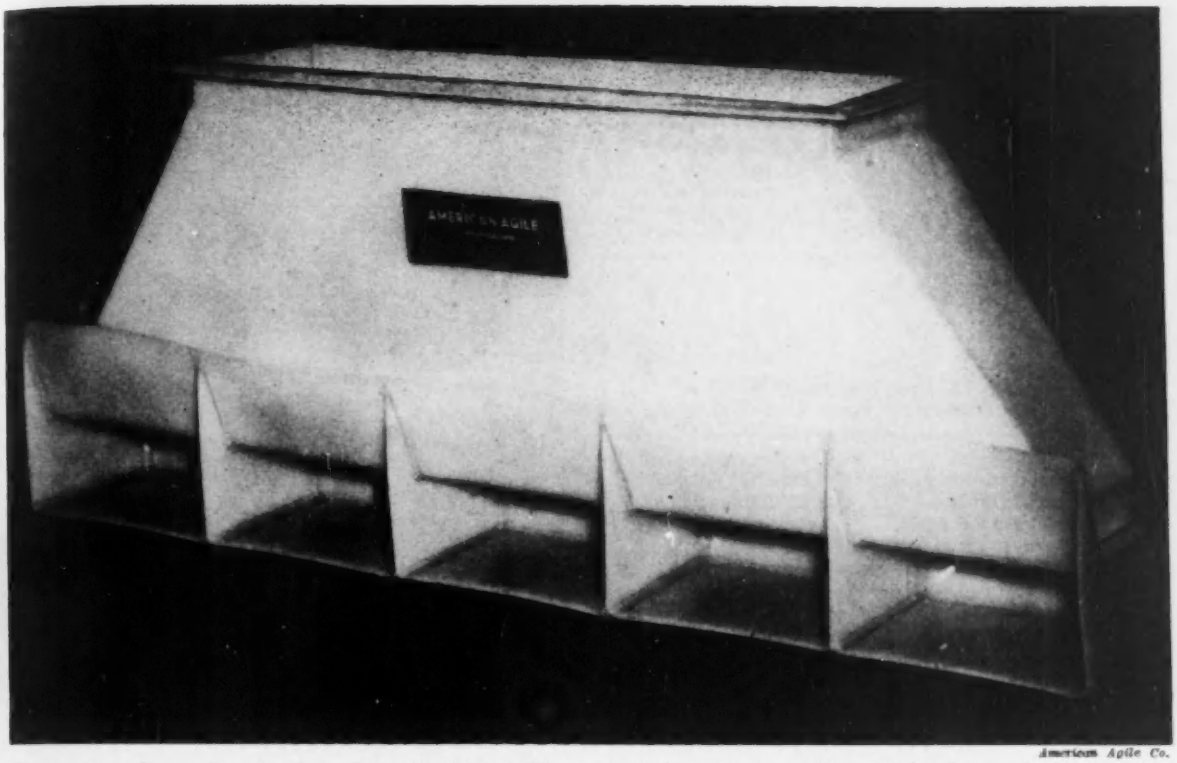
Gasketing Properties

Because of its chemical resistance and low coefficient of friction, much interest exists in polyethylene gaskets Fig. 7(a), bearings, grommets, washers, rings and bushings. Polyethylene bearings are light-weight, non-corrodible, and non-toxic and qualify for many applications, particularly in apparatus such as food preparing or textile machinery where the presence of a lubricant might introduce serious spoilage, or for many household appliances. A powdered lubricant such as graphite can be compounded with polyethylene to provide a very low friction bearing.

The compression characteristics of polyethylene gaskets are compared in Fig. 7(b) with those of tetrafluoroethylene and bonded asbestos. Sandwich construction of polyethylene and bonded asbestos appears to have interesting possibilities. The flexibility of polyethylene rings and bearings allows them to be cut and twisted onto a shaft without removing the glands.

Fabrication

Polyethylene is one of the easiest thermoplastics to fabricate. Parts can



American Agile Co.

Fig. 5—Large fume exhaust hoods can be readily fabricated from polyethylene sheet by welding. The hood shown is five feet wide.

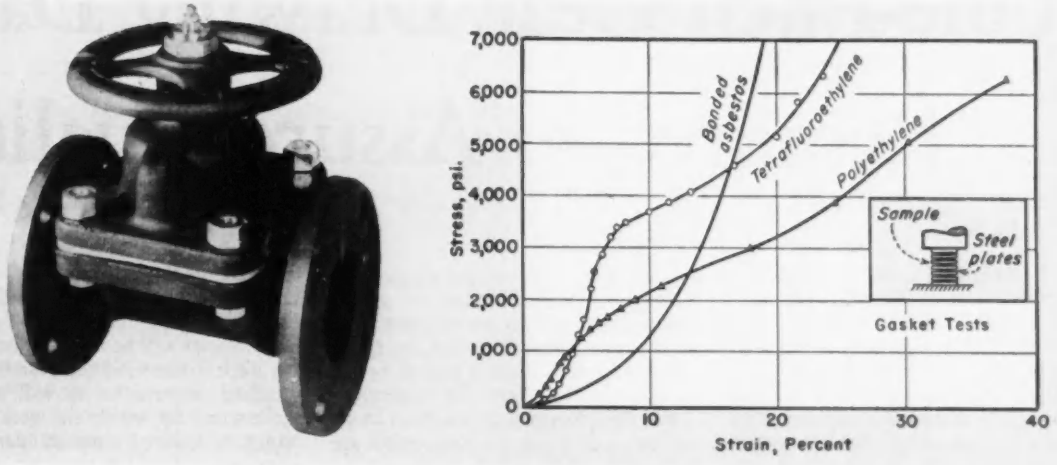


Fig. 7—(a) Heavy flange gasket for this liquid meter has good compression characteristics and resistance to the effects of corrosive liquids. (b) Compression characteristics of polyethylene gasket compared to those of terrafluoroethylene and bonded asbestos.

be formed by injection molding, blow molding, centrifugal casting, extrusion, calendering, solution coating, flame spraying, heat sealing and flame welding.

The formability of polyethylene provides good design flexibility—almost any shape is possible within the limits of the forming equipment.

There appears to be no inherent limitation of size or shape of articles that can be injection molded from polyethylene. Its viscosity at molding temperatures is relatively low. This is advantageous in making thin-walled sections such as flexible tubes, ice cube trays and similar items.

Large tubes and cylinders with uniform wall thickness can be made by centrifugal casting. The dry powdered polyethylene is held against the walls of a rotating, heated metal cylinder by centrifugal force.

Welding of polyethylene by hot gas or electric torches allows the fabrication of items which can't be molded to shape. It is used to fabricate centrifugal castings into large structures.

Flame spraying is a relatively new technique in applying protective surfaces to metal or in building up shapes that can be stripped off.

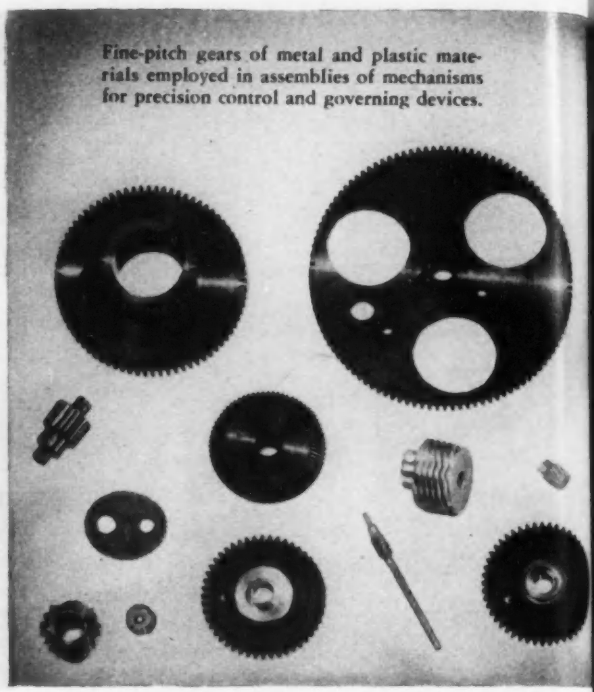
Acknowledgment. **The author wishes to acknowledge the help of the technical staff of the Bakelite Company for most of the data presented.**

Table I—Data That Should Be Given On Drawing for a Fine-Pitch Spur Gear

1. Number of teeth	6. Testing diameter
2. Diametral pitch	7. Class: Commercial or Precision
3. Pressure angle	8. Center distance with mating gear
4. Standard pitch diameter	
5. Operating diameter	

Table II—Data That Should Be Given On a Drawing for Fine-Pitch Helical Gear

1. Number of teeth	6. Hand: right or left
2. Normal diametral pitch	7. Standard pitch dia.
3. Transverse pitch	8. Operating pitch dia.
4. Normal pressure angle (pressure angle of cutter or hob normal to the tooth helix)	9. Testing dia.
	10. Class
	11. Center distance with mating gear
5. Helix angle	



Fine-pitch gears of metal and plastic materials employed in assemblies of mechanisms for precision control and governing devices.

Fine-Pitch Gear Drawing Data Required to Assure Quality

LOUIS D. MARTIN
Gear Engineer, Camera Works
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INFORMATION NEEDED by manufacturing departments as stated on many gear drawings is frequently vague, incomplete and misleading. Often conflicting specifications for backlash are given. While this situation is quite general, it is particularly true of fine-pitch gears. For instance, measurement of backlash may be given as a pin measurement over two diametrically opposite teeth, in which the axis of rotation is ignored, or backlash may be given as a measurement to be obtained with some type of a master. Measurements by the two methods may not necessarily agree.

In complex types of gears, like worm and bevel gearing, the condition is even worse; many drawings slow lack of understanding of fundamental principles and the geometrical aspects peculiar to these familiar types of gearing.

Several Standard bodies are giving this problem serious consideration and hope that a standard format for specifying information, in a logical order, for all types of gearing will be adopted.

For the requirements of gears to be clearly understood by those who are concerned with manufacture and inspection, the gear data should be given on the drawings in a clear and unmistakable manner. In Table I is given the data and the preferred order in which they should be presented on a drawing for a spur gear.

Specifications for helical gears should follow the same general order as that for spur gears but, because both normal and transverse planes must be considered in helical gears, several other dimensions are required. In Table II is given the data and the preferred order in which they should be presented on helical gear drawings.

In Tables I and II, "Operating diameter" is the diameter at which two identical gears operate with each other at a given center distance. The operating diameter will be equal to the standard pitch diameter if the gear is cut to standard proportions, or will indicate the amount by which the gear is enlarged or reduced from standard proportions.

The "Testing diameter" is the diameter at which the gear is tested for size when in intimate contact with a master gear or rack. The testing diameter is usually smaller than the operating diameter by a suitable amount dependent upon the change in center distance needed to provide the required backlash in the mating work gears. The approximate change in center distance for the four classes of backlash (A to D) for fine-pitch gears of 20 deg pressure angle is given in the last column of Table III. These values can be considered as the amount of reduction in operating diameter re-

Table III—Specified Backlash and Center Distance Change for Different Classes of Gears For 20 Degree Pressure Angle

(AGMA Standard 236.03, and ASA B6.11-1951, Inspection of Fine-Pitch Gears)

Class	Diametral Pitch Range	Backlash in Mating Gears, in.	*Approx. Change in Center Distance, in.
A	20 to 45	0.004 to 0.006	0.0055 to 0.0082
	46 to 70	0.003 to 0.005	0.0042 to 0.0068
	71 to 90	0.002 to 0.0035	0.0028 to 0.0046
B	20 to 60	0.002 to 0.004	0.0028 to 0.0055
	61 to 120	0.0015 to 0.003	0.002 to 0.0042
	121 and finer	0.001 to 0.002	0.0014 to 0.0028
C	20 to 60	0.001 to 0.002	0.0014 to 0.0028
	61 to 120	0.0007 to 0.0015	0.001 to 0.002
	121 and finer	0.0005 to 0.001	0.0008 to 0.0014
D	No measurable backlash at any pitch		

* For helical gears of 20 deg normal pressure angle, divide these table values by the cosine of the helix angle to obtain the transverse backlash.

Engineering methods of specifying dimensional data on drawings for fine-pitch gears to promote accurate interpretation of quality requirements by the manufacturing and inspection groups. Proposed drawing format for spur and helical gears. Pin measurements and composite checks as a basis of acceptance or rejection. Method of converting individual error specifications into terms of composite check. Tolerances for Fine-Pitch gears.

quired, in each of a pair of gears, to produce the specified backlash indicated by the letter in the first column.

EXAMPLE: A gear having 45 teeth of 45 diametral pitch and 20 deg pressure angle operates with a similar gear at 1.000 in. mounting center distance, and specifications call for Class A backlash. What is the testing diameter?

SOLUTION: From last column of Table III, for Class A backlash and 45 diametral pitch the change in center distance is given as

(0.0055 to 0.0082 in.)

Therefore, mounting center distance less change in center distance of two work gears in intimate contact is

(1.000 − 0.0055) to (1.000 − 0.0082) = 0.09945 to 0.9918 = Testing diameter, in.

This dimension should be written on the drawing as

Testing diameter = 0.9945 − 0.003 in.

It is usually satisfactory to work to the nearest thousandths of an inch in applying a backlash tolerance to a testing diameter.

Among the pertinent data listed in Tables I and II that should be given on gear drawings is that of "Class". The AGMA Standard 236.03 (ASA B6.11-1951) "Inspection of Fine-Pitch Gears" classifies gears as given in Table IV in two groups: Commercial, which has four classes, namely, 1, 2, 3, and 4; and Precision, which has three classes, namely, 1, 2, and 3.

These inspection standards designate backlash by means of a letter suffixed to the class specification such as: Precision 1A or Commercial 4B. As will be seen from Table III there are four grades of backlash, A to D inclusive; also there are certain grades of backlash that are not applicable to all pitches. As an instance; grade A backlash is not applicable to gears finer than 90 diametral pitch.

Backlash in these standards bears a certain proportionality to tooth thickness. At 100 diametral pitch where the tooth thickness is only 0.0157 in., a backlash of 0.004 to 0.006 in. would be an excessive percentage of the tooth thickness. On the other hand, this amount of backlash might be reasonable in a coarser pitch range where tooth thickness is greater.

The philosophy of specifying quality in accordance with this standard follows the established method of specifying quality in screw threads. When we say $\frac{1}{4}$-20NC4 to designate a screw thread, we immediately know all about it; its tolerances, nature of fit with its mating part and even its gaging tolerances. In like manner, the fine-pitch inspection standard has the same comprehensive controls. For instance, all that need be said about a gear specified in accordance with this standard is: Commercial 4B. By this statement, the exact amount of total composite

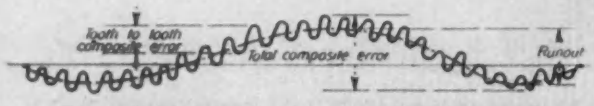


Fig. 1—Indicator reading for a gear checked on a variable center distance fixture. Flicker results from circular pitch error, thickness variation, and profile error.

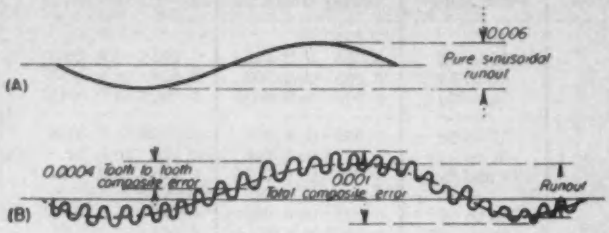


Fig. 2—(A) Permissible sinusoidal variation in run out. (B) Computed tooth to tooth error superimposed on the sinusoidal run out curve.

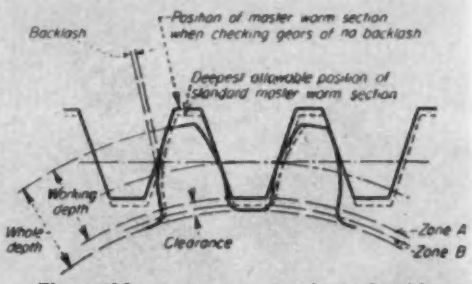


Fig. 3—Master worm section in mesh with a work gear. (Solid lines) Engagement with a gear of standard tooth thickness without backlash. (Dash lines) A gear cut with backlash.

error and backlash is defined. Further, the tolerances on the blank for producing this gear and the master gears used to inspect it are tied in with the quality specification.

Quality control men will find much valuable information in the ten sections of the standard that cover the inspection of all types of gears, gear blanks, master gears, and surface roughness of gear teeth.

Several Standard's bodies are currently working on gear specification formats. An AGMA Standard is in progress for gear specifications, which will soon be released, that gives guides for putting dimensions on all types of gear drawings.

Other valuable information can be found in AGMA Gear Nomenclature 112.02 (ASA B6.10-1950). It is of course recognized that dimensioning of gearing will often vary with the particular needs of a company. Some prefer to give methods information on drawings, while others prefer to put on the drawings only the essential design information and to give manufacturing information on operation sheets. The important objective is to make the requirements clear and complete. Using existing standards will prove helpful.

Backlash tolerance is often omitted from the quality specifications of gear drawings or it is given as a measurement over pins. Pin measurements, while generally satisfactory for obtaining size of the gear when it is still in the machine, are not entirely satisfactory as a basis of acceptance or rejection.

Pin measurements have several limitations that are well recognized:

1. They ignore the axis of rotation. Gears do not stand still; the influence of the displacement of their axes (run-out) is overlooked when two points diametrically opposite each other are measured over pins.

2. Pins are not sensitive to profile error that results from tooth thickness variation and pitch error.

3. Only when the total composite error approaches zero will the pin measurement for backlash agree with that obtained by means of a master on a variable center distance fixture.

Many good gears are rejected because the amount of backlash as measured by pins and that measured by composite check do not agree.

The composite check gives the combined effect of the following individual errors for spur gears: Run out; Pitch error; Tooth-thickness variation; Profile error; and Lateral run out, sometimes called wobble. The effect of lateral run out in spur gears has the same influence on a composite check as lead error in helical gears, because spur gears can be considered as being helical gears of zero helix angle. The composite errors depicted in Fig. 1 are the bases of evaluating relative quality and are exclusive of errors in masters.

As the basis of evaluating quality the composite check comes closest to the truly functional check; especially for instrument gearing, which usually operate with light loads and little backlash.

In the ultra fine pitches, checking individual errors such as profile error, pitch error and tooth thickness variation (even if such errors could be ascertained to the high order of precision demanded of present-day gearing) would not be as useful as checking the effect of their combined influence on each other.

Profile error, pitch error and tooth thickness variation are all affected either adversely or favorably by run out. These errors may cancel each other or they may add to each other, depending on how they combine. In the final analysis, the engaging teeth of the mating gear do not know what combination of individual errors have affected them adversely or favorably. They only recognize that their rate of motion and smoothness of operation is changed.

In highly stressed coarse-pitch gears, where beam strength and surface durability are important, certain individual errors such as pitch and profile error must be controlled within calculated limits, but even in these gears an individual error check is supplemented by the composite check. A learned engineer aptly said: "The composite checking equipment for gear teeth may be considered as the police department of quality control of gearing; it segregates the good from the bad quickly and efficiently. On the other hand, the equipment for checking individual errors is the court of last resort; it tells what corrective measures must be taken and what adjustments made to prevent gears from being manufactured that will not pass final inspection."

Since many gear drawings give tolerances of individual errors, quality control men are sometimes puzzled as to how to convert the individual error specifications into terms of composite check.

Several individual errors are affected to some extent by run out because the eccentricity of the axis of rotation with the axis of the generated pitch circle as the result of run out causes the effective pitch radius to change as the gear revolves. When the pitch radius is different around the periphery of the gear, it follows that some teeth are

closer together in the area where the pitch radius is shorter than in the area where the pitch radius is greater. Run out affects tooth thickness variation, pitch error and, in helical gears, lead error in the same way.

The effect of run out on the transmission of uniform motion is inversely proportional to the diameter of a gear. Consider two disks, one having a diameter of 1 in. and the other of 5 in., each having a hole 0.001 in. off center. The effect of eccentricity in changing the peripheral velocity will be five times more critical on the smaller disk than on the larger disk.

Following this reasoning, it is reasonable to assume that the first tolerance to be established in a gear drive, where uniform angular motion is important, is the permissible sinusoidal variation in velocity that is caused by run out. Having determined this tolerance, it is then possible by means of probability laws to compute the probable maximum tooth-to-tooth error that may be superimposed on the run out curve and yet not exceed a tolerable sinusoidal variation in angular velocity.

For example, assume that the permissible pure sinusoidal run out is 0.0006 in. as shown in Fig. 2 (A). Also assume that the tolerances on the several errors are:

Profile error = ± 0.0002 in.
Pitch error = ± 0.0002 in.
Tooth thickness variation = ± 0.0002 in.
Lateral run out
and/or lead over = ± 0.0002 in.

disregarding the decimals in these values and taking the square root of the sum of the squares, which is a generally accepted procedure for treating variables that may combine randomly with each other, there results

Square of the profile error = $\pm 2^2 = 4$
Square of the pitch error = $\pm 2^2 = 4$
Square of tooth thickness variation = $\pm 2^2 = 4$
Square of lateral run out and/or lead error = $\pm 2^2 = 4$

Sum of the squares = 16
Square root of the sum = $\sqrt{16} = 4$

or

Square root of the sum of the square of the tolerances = 0.0004 in.

This tolerance of 0.0004 in. is the computed tooth-to-tooth error that when superimposed on the sinusoidal run out curve of Fig. 2 (A) results in the graph shown in Fig. 2 (B), where the total composite error (tooth-to-tooth plus run out) becomes 0.001 in. A gear with these specifications would be in Precision Class 1 (Table IV) according to the Fine-Pitch Inspection Standard.

In the method outlined for computing the probable tooth-to-tooth error from the randomly arranged individual errors, a small change in any one of the tolerances will have no practical effect on the final result. For instance, increasing or decreasing any one of the four tolerances by one ten-thousandth of an inch will result in computed tooth-to-tooth errors of 0.000458 and 0.000361 in. respectively.

This method of converting individual error specifications to composite error has been found practical. In a number of instances where this conversion was made, careful checks of the individual errors of specimen gears disclosed correlation within very close limits. It is suggested that the Class that comes closest to the one computed (to the nearest ten-thousandth) be used, as obtained from the inspection standard for fine-pitch gears.

When work gears are checked in intimate contact with a master gear on a variable center distance fixture, attention should be given to the amount that the top of the master gear extends below the working depth of the gear being checked. If the work gear is cut with an appreciable amount of backlash, a master gear of standard tooth proportions may possibly extend too far into the inactive part of the tooth (the area below the working depth.) In this event, gears may be rejected that would otherwise pass inspection.

To be theoretically correct, a separate master should be used for each condition of backlash in order to explore all of the active and none of the inactive tooth profile of the gear being checked. Obviously, this practice would be prohibitive because of the large number of separate masters required.

A good compromise can be effected by permitting the master to extend into the inactive zone of the teeth by an amount considered safe. In Fig. 3, a Kodak master worm section in mesh with a gear is shown under two conditions of contact. The solid lines show a master section engaging a gear of standard tooth thickness without backlash. The dashlines show the same master section engaging a gear cut with backlash. Because the tooth is thinner than standard, the master worm section has penetrated deeper into the tooth and has reached the end of zone *A*. This amount is considered to be the maximum that the master worm section and or master gear can be permitted to penetrate into an inactive zone of the tooth without penalizing production, by making the inspection over critical.

If reasonable care is taken to use generating tools made in accordance with accepted tooth form standards and to keep the tools sharp, the trochoid curve generated at the base of the teeth will never interfere with the tips of the master worm section and or master gear. As shown in Fig. 3, the amount that the master worm section can extend below the working depth is equal to half the clearance minus 0.002 inch.

Master worm sections used in the Kodak Conju-Gage gear checker are made to cover the widest range of backlash practical without penalizing production and still explore the maximum tooth profile distance. Those made to check gears of 20 deg pressure angle, in accordance with the ASA Fine Pitch System, are proportioned so that one master covers the entire range of backlash.

A 20 deg pressure angle worm section will not extend below zone *A*, Fig. 3, when checking gears of Class A backlash (the broadest backlash class allowed by ASA standard B6.11-1951). When checking gears of Class D backlash (no measurable amount), this section will explore 98 percent of the entire profile at 20 diametral pitch and

Table IV—Tolerances for Fine-Pitch Gears
(AGMA Standard 236.03, and ASA B6.11-1951, Inspection of Fine-Pitch Gears)

Class	Total Composite Error, in.	Tooth-to-Tooth Composite Error, in.
Commercial 1	0.006	0.002
Commercial 2	0.004	0.0015
Commercial 3	0.002	0.001
Commercial 4	0.0015	0.0007
Precision 1	0.001	0.0004
Precision 2	0.0005	0.0003
Precision 3	0.00025*	0.0002

* This value would be the result of selection and segregation.

Note: Commercial gears should always be given first preference because they are cheaper to produce. Experience has shown that they are suitable for most fine-pitch applications.
Precision gears should be avoided unless the functional requirements make their use imperative. When used, due consideration must be given to their greater cost. Usually, precision gears cannot be produced by cutting alone. Subsequent refining operations or selection must be employed.

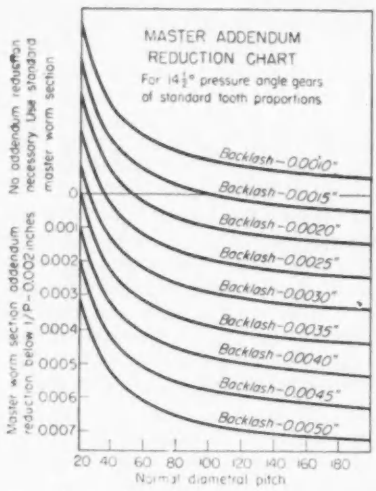


Fig. 4—Family of curves that indicate when the addendum of a Kodak master worm section should be shortened to avoid contact below critical clearance zone area.

80 percent of the entire profile at 100 diametral pitch. Since the mating gear always has a minus allowance on outside diameter, and the teeth seldom, if ever are sharp right up to the addendum circle, for all practical purposes the master worm section checks all of the effective working profile of fine-pitch 20 deg gears in any class of backlash.

Gears of 14½ deg pressure angle made to standard proportions are more susceptible to the encroachment of the master worm section into the inactive part of the gear tooth because the base diameter, where the involute curve originates, of such gears is larger than that of corresponding gears of larger pressure angles; consequently, the base circle is nearer to the pitch and root circles. While the Kodak master work section has been shown in the illustrations, practically the same condition exists when a circular master is used.

By means of the family of curves, shown in Fig. 4, it is possible to determine when a Kodak master worm section or master gear should be modified by shortening its addendum to avoid contact below zone *A*, Fig. 3. With this chart, it is also possible for the gear engineer to evaluate the risk of checking too much of the inactive profile and to decide when master gears or racks of modified tooth proportions should be used.

In the 14½ deg system, of course, all gears with less than 32 teeth are undercut, and undercut pinions should always be avoided. The ASA 20 deg system gives values for enlarging undercut pinions in the range of 7 to 17 teeth inclusive. Above 17 teeth no undercut exists in this system. Since there is no equivalent standard for 14½ deg enlarged pinions with no undercut, the values given in Fig. 4 are based on standard proportions.

Isotopes Can Control Automatic Processes

NUCLEAR GAGING can be integrated with production control to get improved accuracy in manufacturing coated products, according to Industrial Nucleonics Co., Columbus, Ohio. Gage indications, expressed as small voltages, actuate recording devices that provide permanent records of each production run and at the same time signal for production-line adjustments that can be made in a matter of seconds, without stopping the high-speed machinery.

The gages provide 100 percent continuous sampling. They are not influenced by temperature, dirt, humidity, and they do not contact the moving sheet at any time. A sealed capsule of radioactive Strontium-90 emits beta rays. As the material being measured moves past the aperture between the source and the detector unit (a special type of ionization chamber), the amount of radiation passing through the material varies according to the density of the material.

The beta rays that get through to the detector unit ionize an inert gas and thus create a tiny voltage that provides a recording and controlling signal. Since the gage is calibrated, variations in beta-ray transmission cause changes in signal that vary directly with change in weight per unit area. Recalibration is not necessary. While the radioactive isotope is inspected every six months, its expected life is 30 years.

At Carborundum Company's Coated Products plant five gages installed on a coated-abrasive processing line have an accuracy within one percent. Gage one measures backing weight of the paper, cloth, fiber or combination. Variation in unit weight at this point affects future coating operations, such as adhesive roll setting. Gage two picks up weight of backing plus weight of adhesive coat. Gage three measures weight of backing plus weight of adhesive plus weight of abrasive. Gage four measures total weight after preliminary cure and before final adhesive coating. Gage five measures final weight after this adhesive application.

Signals from the gages are translated into a trace on pen recorders. Superimposing the trace signal from gage one and the signal from gage two (each a different color) on one recorder, provides a visual comparison of machine coating. The two superimposed signals from gage two and gage three on a second recorder show immediately any deviation from specification. When the two traces overlap, the material is being made properly. Any change is immediately noted, and its source is known so that proper correction in adhesive roll settings, abrasive feed, or special speed of paper through the machinery can be made.

This installation puts an end to trial and error production control. To control the process formerly, it was necessary to stop machines, take samples, check each sample and then adjust rolls and feeds. As a result close control was expensive and reject rate ran high.

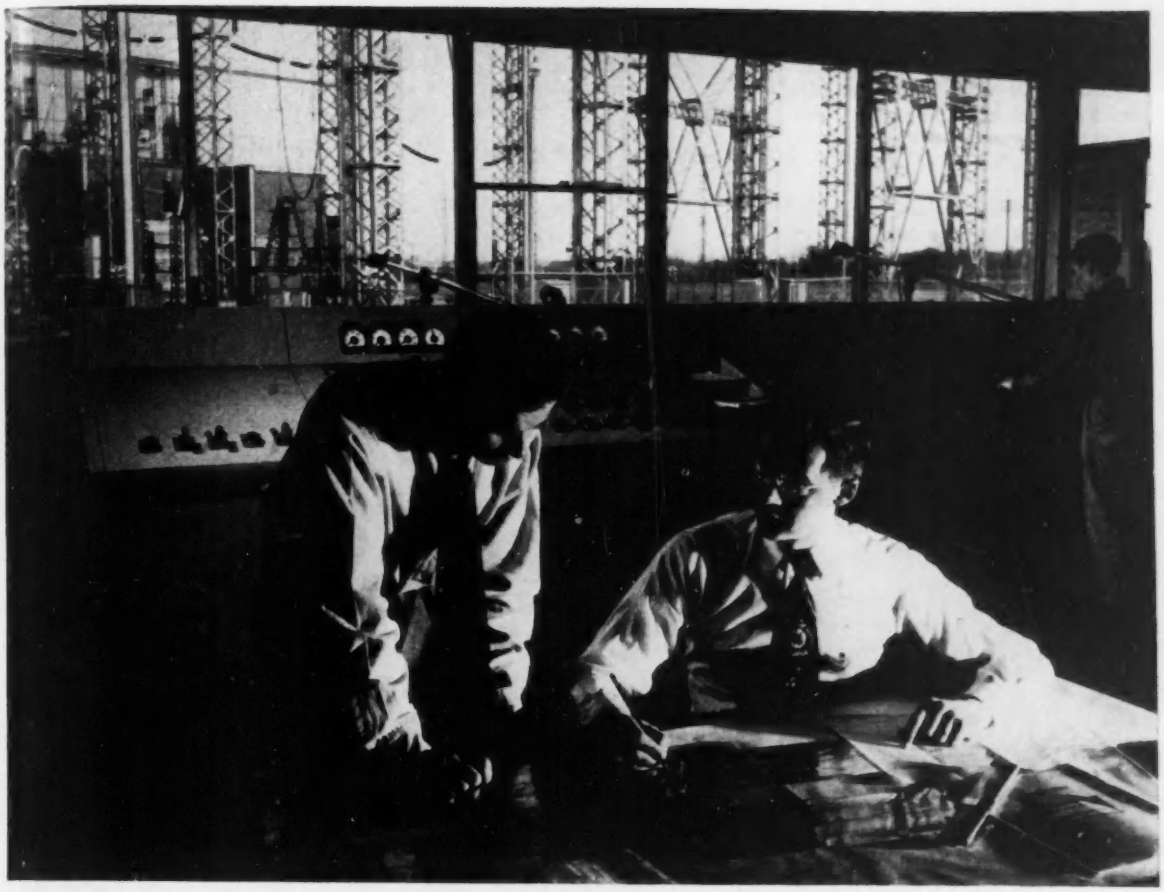
According to Carborundum and Industrial Nucleonics engineers, these advantages result from the use of radioactive isotope gages:

1. Unvarying uniformity no matter which type of coated product is ordered.
2. Close duplication of previous orders, since graphic records are kept of each run.
3. Elimination of slow and cumbersome hand-testing.
4. Reduction of machine downtime.
5. Savings in expensive materials. "Overshooting" on specifications to make sure of meeting minimum thickness requirements can be eliminated. Processed material will no longer be wasted by destructive testing.
6. Researchers can use the equipment to study new specifications and develop new grades of coatings to meet specific production problems.

Nuclear gaging lends itself particularly to the control of processes that have several steps. Step-by-step permanent records and the ease in locating trouble spots are advantageous in high-speed continuous production lines.

The integration of continuous gaging with production control on an automatic basis is said to pay for itself in a matter of months. Process control is simple and requires no additional operator skills.

TECHNICAL NEWS



NERVE CENTER OF GE's new Switchgear Development Laboratory is this master control room that faces onto the test cells. Panoramic glass in background is shatterproof to protect observers during tests. Magnetic and cathode ray oscillographs supply engineers with film record of circuit characteristics a few minutes after the experiment is completed.

General Electric Opens Powerful Test Laboratory

THE MOST POWERFUL SHORT CIRCUITS ever produced—5,250,000 kva—are created for power equipment tests at the General Electric Company's new Switchgear Development Laboratory in Philadelphia. These surges will be used in developing and testing circuit breakers and other equipment for industrial power systems.

Heart of the new lab is a pair of generators designed especially for testing. When operated in parallel, the two units can deliver 5,250,000 kva assymetrical or 3,200,000 kva symmetrical at 15.5 kv, 3 phase. The stator of each generator is mounted on spring-steel "legs" that permit the stator to rotate through a small angle and still remain in perfect alignment with the rotor shaft. Shocks caused by the sudden short circuits are borne by these springs instead of the generator windings and foundations.

Controls of the generators and equipment under test are located in a control room that fronts on the five test cells. This room is protected by panoramic shatterproof windows to make it possible for engineers to watch experiments.

An all-steel test building opposite the control room is divided into two sections. One contains the incoming power source equipment, distribution apparatus, the generators, and auxiliary service equipment. The other is equipped with a machine and assembly shop facilities for preparing apparatus that is to be tested.

Five test cells are ranged along one side of the test building. A bank of single phase transformers is used to supply short circuit current as high as 500,000 amp at 600 v to one of the cells.

During tests, magnetic and cathode ray oscillographs connected into the test circuits automatically record electrical phenomena taking place in the equipment. And the film records permit study of this data after the test has been completed.

GE listed these four engineering objectives at the dedication ceremonies: 1) to develop circuit interrupters of higher ratings to keep pace with the growth of electric utility system; 2) to speed the development of switchgear equipment; 3) to study the effects of voltage, current, frequency, and other conditions affecting switchgear equipment; 4) to reduce cost by investigation of mechanical design.

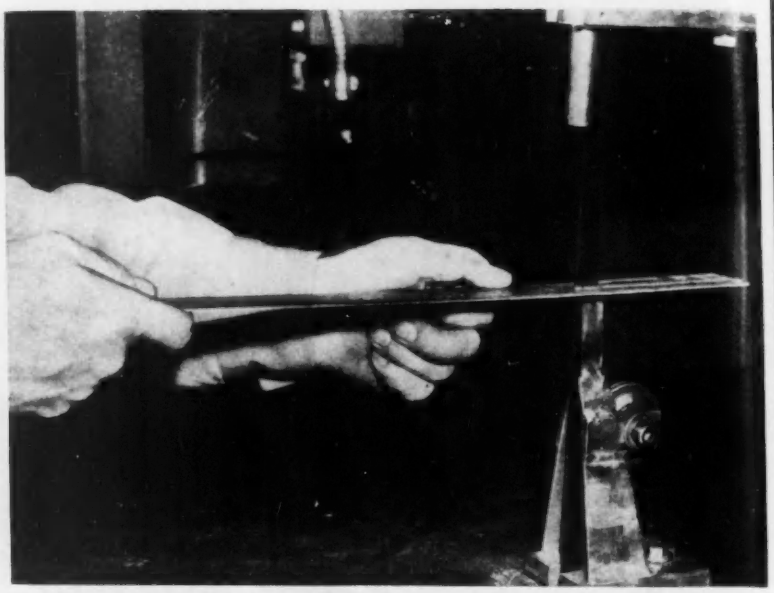
PROCESSES: Box Strapping Cuts Stainless Steel Better Than Saw Blades

SAN DIEGO—Ordinary box strapping used to wrap shipping crates will last longer than regular band saw-toothed blades when cutting stainless steel and other high alloy steels. Solar Aircraft Company made this discovery during a program to reduce costs on saw blades.

During band sawing at high speeds, the friction of the saw blade quickly heats the metal being cut to the melting point and burns its way through. Saw blades have been toothed largely on the theory that the teeth act as tiny scoops to bring oxygen to the metal being cut and to speed the burning action. Solar found that toothless blades harden and roughen within the first few seconds of use to a point where they scoop oxygen as well or better than blades with teeth. They tried scrap box banding and found it lasted longer than fabricated saw blades.

In order to function properly, the boxstrap must have a speed of at least 5,000 surface ft per minute; ideal speed is between 11,000 and 15,000 feet per minute. To date, a speed of 7,550 has been used to cut stainless steel sheeting up to $\frac{3}{16}$ in. thick, just as well as with saw-toothed blades.

Solar sees two big advantages for the new technique: a big cost reduction, and greater safety for saw band operators. The strap is butt welded into a continuous loop and total costs run about 10 cents, compared with a cost of $3.09 for a toothed blade. On a 36 in. band saw that uses 1,000 feet of ordinary saw blade in two weeks, Solar estimates an annual saving of $4,800. The old method requires 53 blades in the two week period that the new method uses only three strap blades; making a saving in blade cost and down time.



TOOTHLESS BAND SAW BLADE made from ordinary steel boxstrapping material cuts stainless steel sheet and high alloy steels at the Solar Aircraft Company.

Safetywise, there are two factors that make the new blading desirable. When the boxstrap breaks, it doesn't whip like an ordinary saw blade. It just folds up. In addition, the new blade will not drag a finger or hand into the machine. An operator has pressed a gloved hand into a boxstrap blade running at 7,500 ft per minute for as long as two seconds and got only a mark on the glove.

Solar finds that the boxstrap blade will cut stainless steel and high alloy steels. They have tested the new technique on tool bits, files and cobalt steel, as well as production cutting of stainless steel sheet.

New Reversal Paper Makes Positives Without Negatives

EASTMAN KODAK COMPANY revealed to the annual meeting of the Blueprint and Allied Industries that they have been trade testing a new reversal photographic paper that produces a positive print without a negative.

Unlike conventional papers such as Kodak's own Autopositive paper, the new paper permits the direct production of positive prints with conventional equipment and processing. This emulsion reacts to light in a manner opposite to ordinary papers used by photographers. When this reversal paper is exposed to light and developed in a fogging developer, the unexposed areas turn black.

The fogging action of the developer is inhibited in those areas which are exposed to light and they form a positive image.

Photostat Corporation has been distributing the paper for Kodak.

Process Plates Aluminum At Room Temperature

NATIONAL BUREAU OF STANDARDS has developed a process for electrode-depositing aluminum at room temperature. The technique produces dense, ductile deposits of the metal from a new type of organic plating bath. Composed of an ether solution of aluminum chloride and a metal hydride, the new bath is expected to find important application for electroforming articles with close inside tolerances, and for providing various types of equipment with a thin protective coating of aluminum.

Because aluminum is so far above hydrogen in the electromotive series of the elements, it has never been deposited from aqueous solutions since these always contain some hydrogen in ionized form. Aluminum is usually produced from a bath of fused cryolite and aluminum oxide. However, this process must be carried out at a high temperature, and the metal is obtained in a fused state, unsuitable for electroplating or electroforming. Electrodeposition from nonaqueous solutions has been tried in the past, with some success, but the procedure was too difficult for practical applications, and the deposits were lacking in purity, ductility, and other desirable qualities.

This new aluminum plating bath is

prepared by adding either lithium hydride or lithium aluminum hydride to an ethyl ether solution of anhydrous aluminum chloride. For best results, the ether should be anhydrous and alcohol-free. The concentration of the aluminum chloride is not critical and may vary from 1 to 4 molar. Current densities may be as high as 4 or 5 amperes per square decimeter. But if thick deposits are desired, the current density should not be greater than 2 amp/dm^2. Because of the high concentration of aluminum chloride in the ether, the bath is not as flammable as would normally be expected.

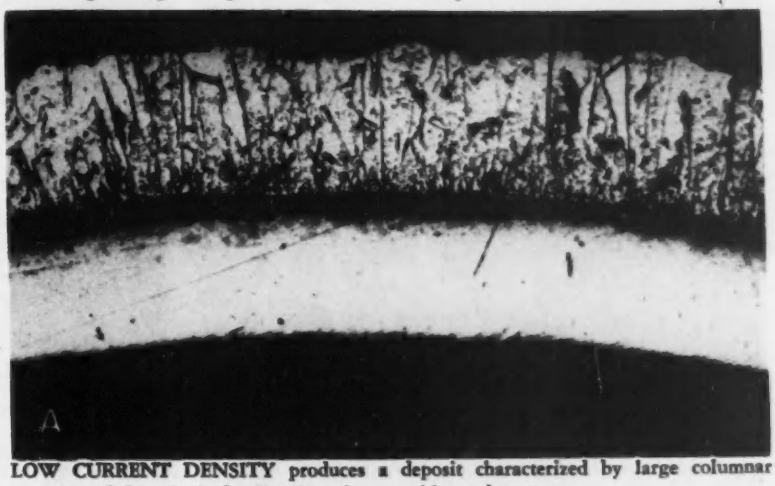
To prevent the entrance of moisture, the bath is prepared and used in a closed container consisting of a glass plating vessel with a tightly fixed polyethylene lid. Anodes of aluminum rod pass through the lid, and the objects to be plated (cathodes) are introduced and removed through a central hole which is ordinarily kept closed with a rubber stopper. If hermetically sealed, the bath will keep for several weeks; however, under ordinary operating conditions, the solution slowly deteriorates and eventually gives streaked and brittle deposits.

No agitation of the bath is necessary. The quiet bath permits the sediment from the anodes to settle to the bottom of the vessel, making bagging of the anodes and filtration of the solution unnecessary. The composition of the bath is easily controlled since the only constituent that changes appreciably in concentration during the plating process is the lithium hydride. Occasional additions of lithium hydride increases the life of the bath until the lithium hydride becomes insoluble and the bath can no longer be used.

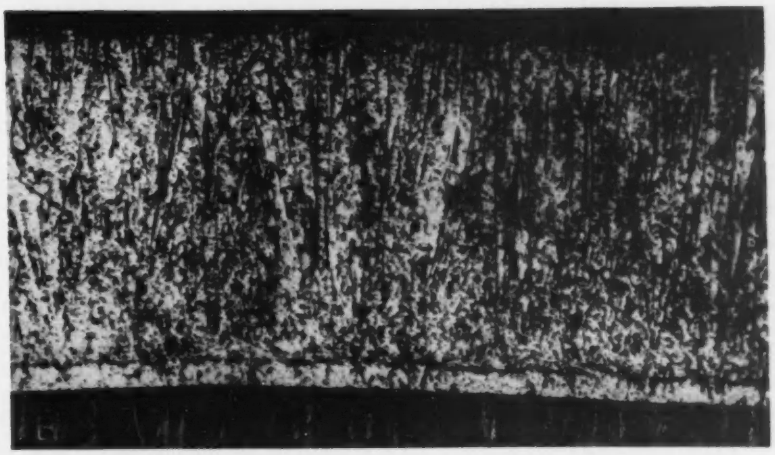
When sufficient lithium hydride is used, the deposits are white, matte and quite ductile; but if the lithium hydride content is too low (less than 3 or 4 g/l,) the deposits becomes hard, brittle, and grey. Still further reduction of the hydride content produces deposits that are dark and stressed and that often crack or peel from the cathode. Ordinarily deposits 0.01 in. or more thick are visibly crystalline, but this effect can be reduced somewhat by adding a small amount of B,B′-dichloroethyl ether. Pitting, which frequently occurs in aqueous baths, is practically non-existent in the ether bath.

Cathode and anode efficiencies for the process are approximately 100 percent. Deposits 0.05 in. thick have been prepared and thicker deposits are possible if the sharp edges of the cathode are shielded to prevent treeing.

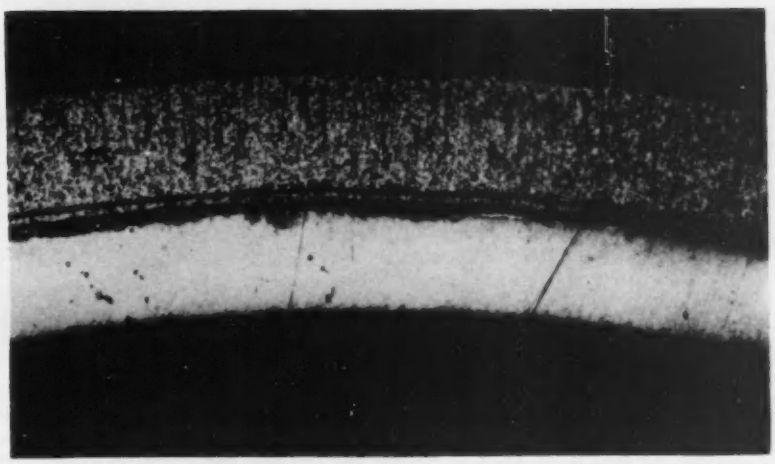
PHOTOMICROGRAPHS OF aluminum deposits obtained with new organic plating bath of lithium hydride and ether solution.



LOW CURRENT DENSITY produces a deposit characterized by large columnar crystals and deposits is ductile. Deposits are white and matte.



PERIODIC REVERSE CURRENT tends to refine grain structure somewhat.



ADDING B, B'DICHLOROETHYL ETHER results in a very fine grain, but deposit is brittle. Low lithium hydride content in bath also makes plating brittle.

1.—LAMINAC RESIN is mixed with a filler of mica, glass fiber, nylon or cotton flock and curing catalysts in new open mold casting process. Mix is then evacuated using a vacuum of 30 in. of mercury. Cobalt napthenate speeds up curing.

2.—TWO COMPLEMENTING MOLDS OF RUBBER, jacketed in plaster of paris, are clamped together and placed on vibrator for filling. Vibrating motion distributes mix evenly throughout the mold. Resin gives off little heat during curing.

Fast Low Cost Process Molds Plastic

A new open mold process casts electrical components quickly and economically according to the Induction Heating Corporation of Brooklyn, New York. Replacing parts formerly made of porcelain, brass or Micalite, these components are made of thermosetting polyester Laminac with mica, glass fiber, nylon or cotton flock as filler. Small amounts of cobalt napthenate are added to speed up the curing during large scale production.

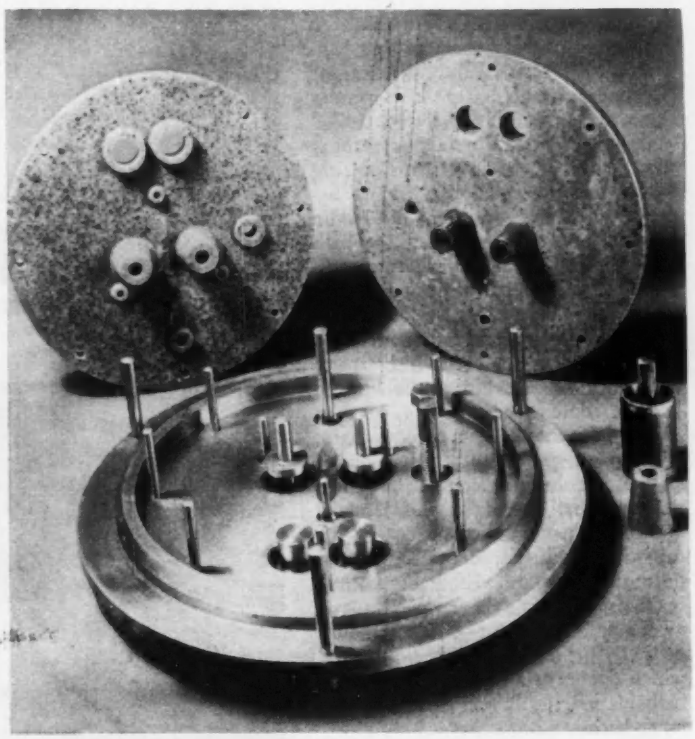
Molds are made of machined steel, rubber, plaster or reinforced Laminac. The plastic is not sensitive to air, so it is air set and oven cured.

Three advantages are claimed for the process: 1) Reduced costs; 2) fewer finishing operations; and 3) fewer assembly operations.

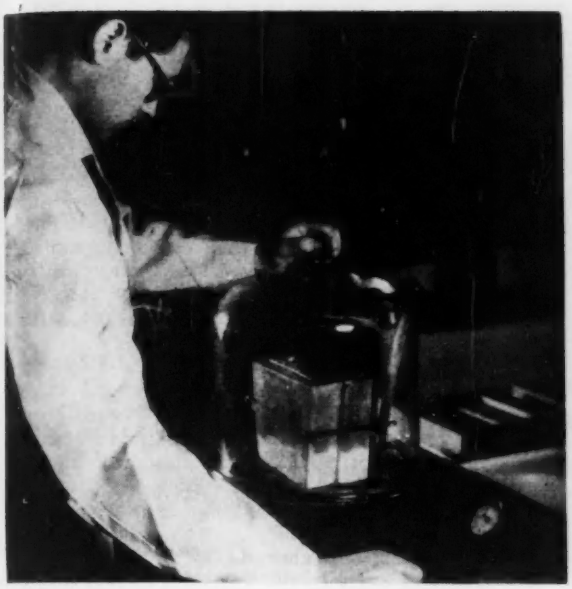
Cost reductions have been impressive with case histories reporting savings up to 80 percent of former costs. Since the material holds dimensions well, finished parts require no grinding, filing, buffing, drilling, or engraving. And tapped, countersunk, and plain holes can be molded into the part. The process also permits molding in one piece parts that formerly were made separately and then assembled.

Electrical properties of the components are claimed to be excellent. These include: high moisture resistance, good insulation, high arc resistance and voltage breakdown strength, and low dielectric and power factor constants.

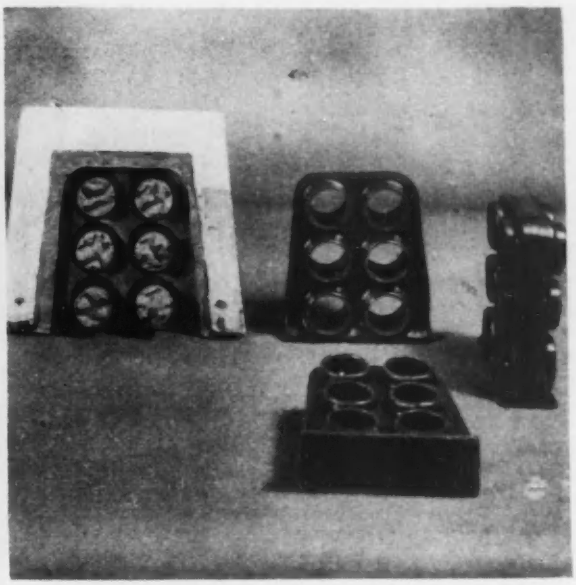
Parts such as plastic tubing and pipe fittings can be placed in the mold before pouring. Imbedded in the Laminac, they are protected from shock and vibration as well as from corrosive atmospheres.



LAMINAC TRANSFORMER COVER AND STEEL MOLD that produced it. Part was formerly made of Micalex and cost $20.00. Laminac part costs $4.00 and weighs 50 percent less. The old cover required porcelain bushings that had to be assembled to the cover. Bushings are molded right to the cover in the new process. Castings are occasionally post-cured in an oven to obtain optimum electrical properties rapidly and to prevent change due to aging.



3.—FILLED MOLD is evacuated to complete "filling out" of mold. Extra mix is added if necessary. Resin is not sensitive to air and is cured in the open mold. Glass cloth placed around mold inserts prevents cracking around holes and improves strength.



4.—AFTER CURING, finished product (right) is removed from mold and requires no filing, grinding, buffing or drilling operations. At left, is one half of a mold showing how the rubber is jacketed with plaster. Other molds are made of plaster or steel.

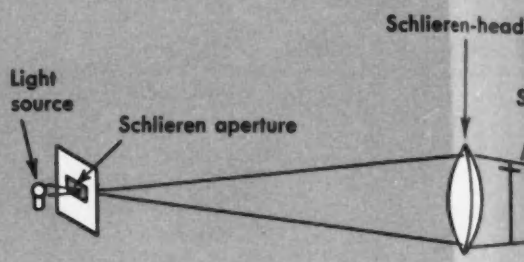
Electrical Insulators From Laminac Resin

TYPICAL PLASTIC PARTS made by new technique. These were all made in open molds, air set, and oven cured. Tapped, countersunk, and plain holes are molded into the component to minimize finishing operations. Finished parts have high arc resistance and low dielectric and power factor constants. Molding process permits savings in cost and weight. The name plates were cast from plaster molds and raised letters are molded in. Formerly plates were made of a low melting alloy and cost about $1.00. Plastic name plates cost about 15 cents. Induction Heating Corporation developed the process to make components for their own equipment, but are now doing custom molding for other manufacturers.

Master Diagram For High-Speed P
Used In Principal T

Optical components essential in the type of camera illustrated.

High-speed cameras generally can be fitted into the framework of a master optical diagram. This diagram must include a schlieren optical system, as it is an integral part of at least one important high-speed photographic method. A refocusing system, essential in several high-speed cameras, must also be included. The schlieren head focuses an image of the schlieren aperture at the knife edge. Irregularities in refractive index of a transparent subject disturb this focus. Consequent interruption of some light rays by the knife edge causes optical irregularities of the subject to be photographed on photo-sensitive film.



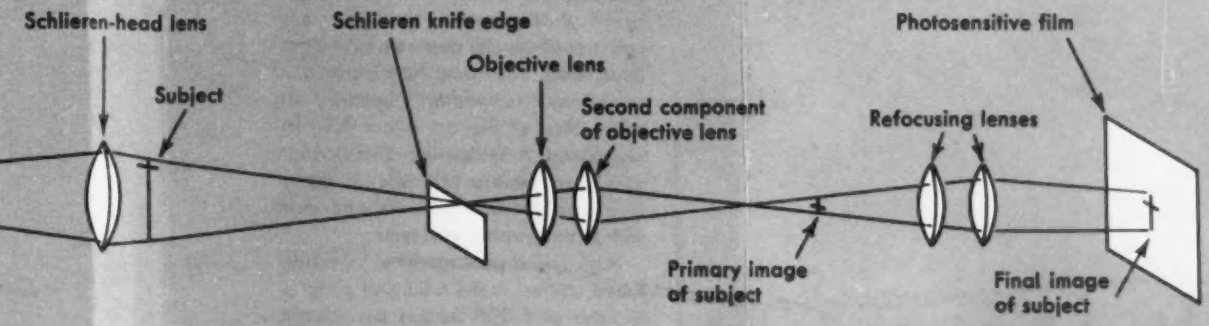
Omission of schlieren aperture and knife edge converts from schlieren to shadowgraph. Removing schlieren head also, and relocating light source, would provide a conventional photographic arrangement with reflective illumination of subject. All these changes can be made with the rotating-prism camera. Rotation varies the extent of refraction of light upon entering and leaving prism, causing image to move with film. Slotted cylinder around prism (not shown) may act as a shutter. Prism may be two- (shown), four-, or eight-sided. Prism surfaces and film frames are only optical components present in multiple.

In the NACA-Miller I camera, and the recently developed Battelle camera, stationary refocusing lenses are used. Primary image is formed on surfaces of a series of reflector pairs. With 90-deg angle between reflectors, a translational motion is imparted to reflected light rays. Stationary refocusing lenses consequently "see" the primary image as a series of moving images formed by the series of reflector pairs. Refocusing lenses match the motion of the secondary images with the movement of the film by providing a suitable ratio of secondary-to-primary image dimensions.

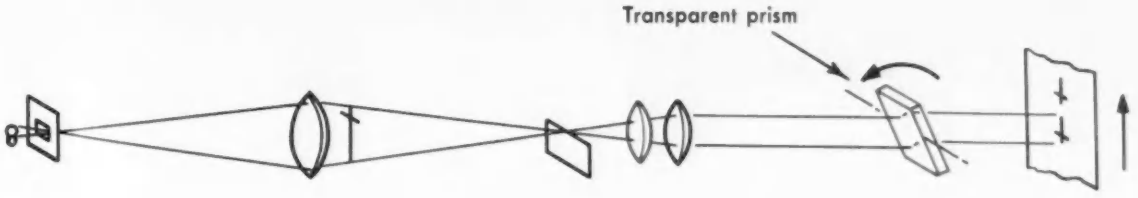
Top speeds for optical compensators are achieved with refocused revolving beams, but with inherently low relative apertures. Primary image formed on rotating plane-mirror surface is "viewed" as a stationary image by refocusing lenses, despite rotating of reflected beam about mirror as center. Hence, each refocusing lens in turn forms a stationary image on the stationary photo-sensitive film as the revolving beam sweeps across that lens. Original NACA-Miller II form produced over 500,000 frames per second, in 200-frame series. Refocusing lenses were arranged in six nearly parallel arcs.

peed Photography And Modifications
cipal Types Of Cameras

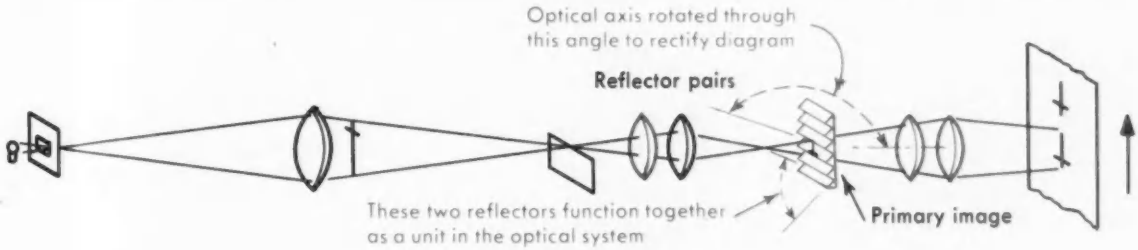
ated. _____ Optical components optional in the type of camera illustrated.



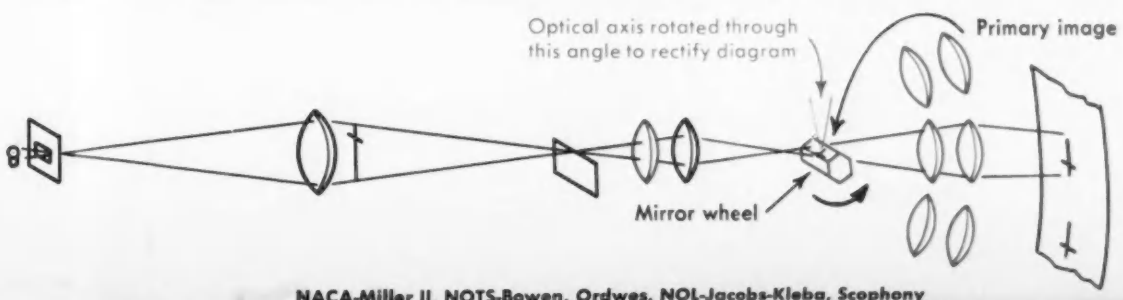
Master Diagram



ERPI, Eastman Kodak, Wollensak Fastax, Brailsford and Schrubb, Acmade


Optical axis rotated through this angle to rectify diagram
Reflector pairs
These two reflectors function together as a unit in the optical system
Primary image

NACA-Miller I, Battelle



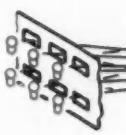
NACA-Miller II, NOTS-Bowen, Ordwes, NOL-Jacobs-Kleba, Scophony

Some of the older high-speed motion-picture cameras use multiple objective lenses. With the subject at infinity and the entire objective lens moving at same speed and in same direction as the film, optical compensation would be complete. With closer subjects, objective lens would need to move more slowly than film. With objective divided into stationary and moving components, suitable adjustment of stationary component causes moving component to "see" an object at any given distance as if it were actually at the correct distance for complete optical compensation.

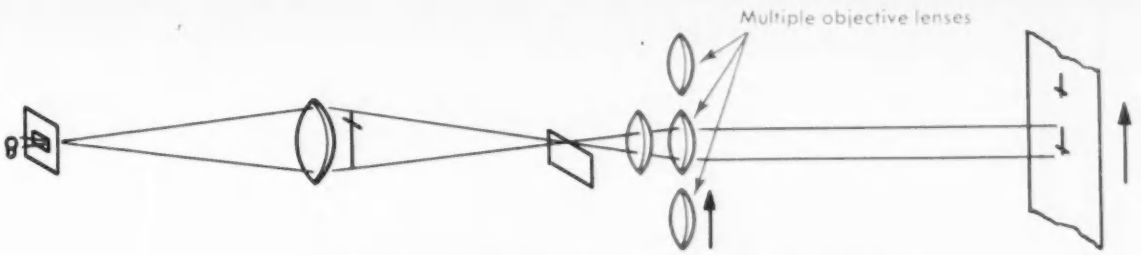
A light beam reflected from a rotating mirror revolves about the mirror. If an image is focused beyond the point of reflection, by a lens placed ahead of that point, the image moves with the revolving beam. Its motion can be made to match that of the film. In the Suhara camera, each mirror surface subtends an angle of 45 deg from the axis of rotation. An undesirable rotation of the image about the axis of the light beam results. In the Scophony camera, the light beam passes through the objective lens both before and after reflection from the surface of the rotating mirror.

Sometimes an optical system is branched at two stages in different manners to form a double multiplicity of optical systems. A number of rotating-mirror cameras can be set up side by side, and a slotted disk, or some other type of shutter used to synchronize these parallel cameras. Each image is taken from a slightly different viewpoint. By the time the last camera has exposed a frame, the first is ready to operate again. Similar combinations of basic camera designs are possible. The Baird camera has exposed photographs at rates up to 120,000 frames per second.

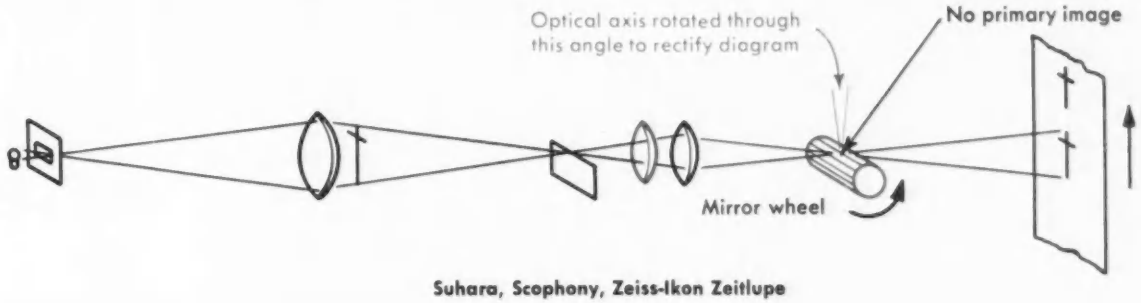
The Cranz-Schardin system, using no moving parts, is applicable only to schlieren photographs or shadowgraphs. Solid objects appear only in silhouette. From any one source, light is focused by the schlieren head into only one of the multiple objective lenses. Various means are used to cause the light sources to operate in succession, and each image is taken from a slightly different viewpoint. The system cannot be used to photograph luminous objects by their own light. Length of series is limited to the number of light sources and objective lenses that can be used. Projectability is sacrificed and resolution is limited only by lens and film quality.



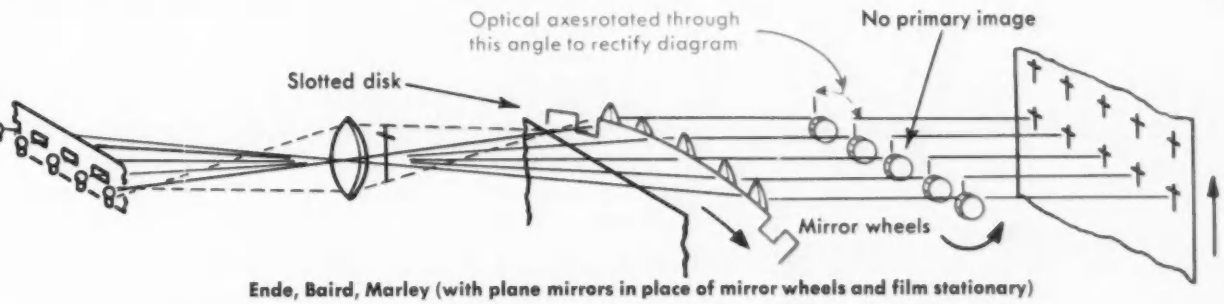
In 1883, Mallard and LeChatelier published photographs determining flame speeds. The field was limited, by screening, to a line extending in the direction of flame travel. With lens stationary, the photosensitive material was moved steadily at right angles to the uni-dimensional image. Each finite movement constituted a new frame. Several modern devices for ultra high speeds use this system, with several uni-dimensional fields coordinated to form a television-type image. By a complex optical system, O'Brien and Milne place the uni-dimensional images end to end.



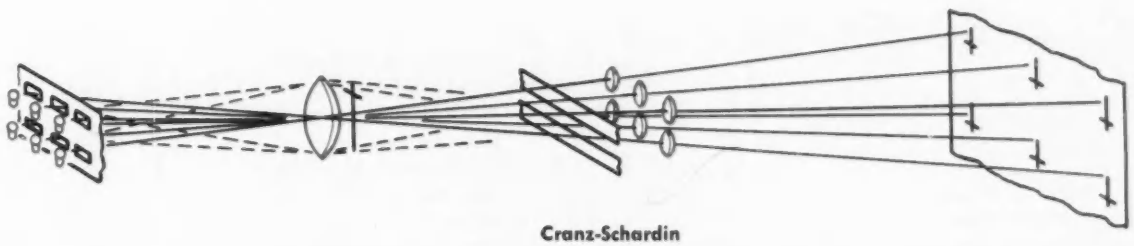
Jenkins, Wyckoff, GE-Prince-Rankin, Askania, Vinten, Merlin-Gerin-Debuit



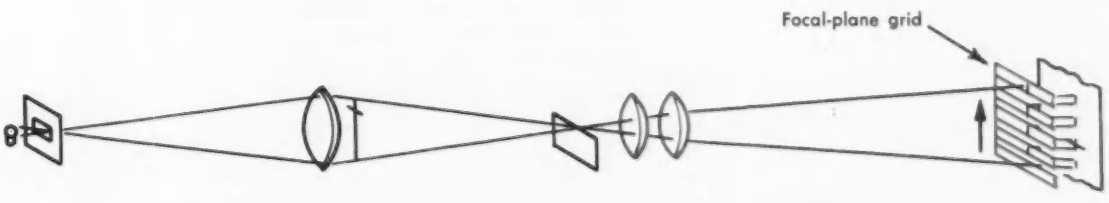
Suhara, Scophony, Zeiss-Ikon Zeitlupe



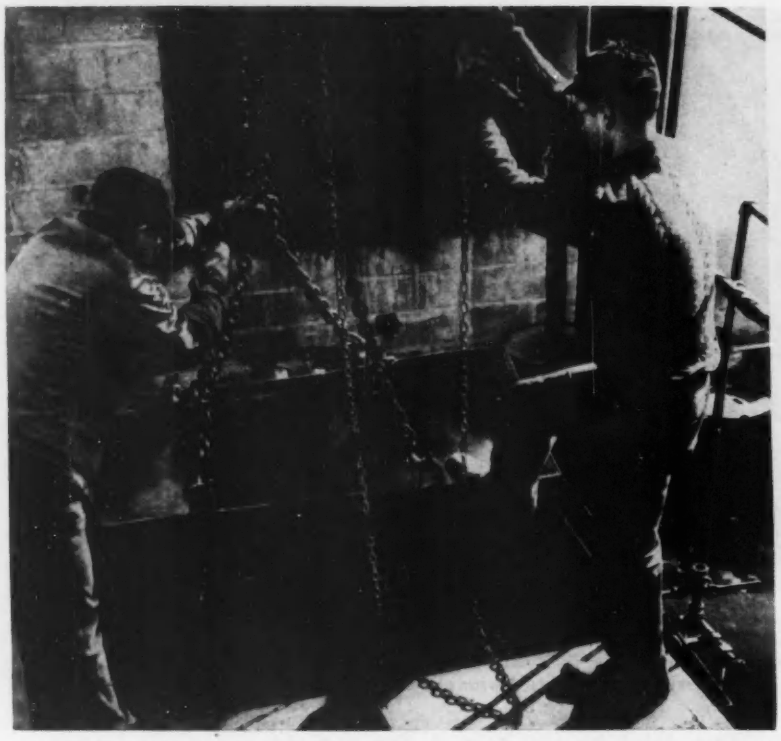
Ende, Baird, Marley (with plane mirrors in place of mirror wheels and film stationary)



Cranz-Schardin



O'Brien-Milne, Eastman Kodak-Tuttle, Ballistics Research Laboratory—Sultanoff



START OF CHEMICAL PROCESS for refining metal from scrap is leaching metal with acid. Workmen are lowering a basket of copper scrap into acid at CCC's pilot plant. In commercial installations, this and all other processes will be completely mechanized.

MATERIALS: New Process Will Boost Copper, Nickel, and Cobalt Supplies

CHEMICAL CONSTRUCTION COMPANY, a subsidiary of American Cyanamid Company, has announced a revolutionary new technique for obtaining practically pure metals by treating ore concentrates with chemical methods instead of smelting and refining processes. Electrolysis and smelting are replaced by acid leaching in this process that should materially increase world supplies of copper, cobalt, and nickel, by converting low grade ores and scrap into usable metal.

Big advantages seen by CCC for the new process include: (1) production of pure metals at lower costs; (2) production of metals from scrap heaps and low-grade ores now not economical to mine; (3) reduction in transportation costs since refineries can be located near scrap sources or at mines; (4) finished product is a pure powder, easier to handle than pigs.

Each commercial application requires specific adaption of the process for the ore and metal to be recovered. However, in general, this is how the process works:

(1) Refiners prepare a concentrate of the ore by conventional flotation-methods.

(2) Concentrate is converted to a water slurry and introduced into an autoclave.

(3) Acids or ammonia leach the slurry.

(4) Metals are recovered by using suitable reducing agents. By varying operation conditions the different metals are produced separately as powders that can be pressed into forms ready for market.

The process is so economical that CCC claims the cost of scrapping existing smelting facilities and installing new ones for chemical refining, can be paid for in about three years from operating savings.

CCC expects their new process will be adapted widely in the mining industry. To date, a nickel-copper-cobalt process has been developed in collaboration with Sherritt Gordon Mines Limited; and a cobalt process has been tailored for the concentrates of mines of the Howe Sound Mining Company in Idaho, and the National Lead Company in Missouri. Effects of the new process should be felt by autumn of this year.

Howe's plant, scheduled for completion this summer, will boost world production of cobalt 40 percent when it starts processing 35 tons of 20 per cent cobalt concentrate per day. The plant will produce 2,000 tons of pure cobalt metal annually; this is 50 per cent of U.S. consumption in 1950.

National Lead expects to turn out 700 tons of cobalt, 900 tons of nickel, and 700 tons of copper each year when their plant is completed in mid-1953.

Sherritt's installation at Edmonton, Alberta will be the second largest nickel refinery in the Western hemisphere when it is completed in the fall of 1953. The plant will produce 8,500 tons of nickel, 1,000 tons of copper, and 150 tons of cobalt each year.

Another adaption of the process was developed with the help of the Chemetals Corporation and will produce electrolytic copper. The new process can produce copper powder better than 99.9 percent pure from any form of copper scrap, brass scrap, or blister copper. This may increase the availability of this form of copper as well as reducing the cost.

Veteran nickel refiners admit that CCC's process is a good one but claim it will remain competitive with smelting only as long as the U. S. supports it financially. They point out that the first step requires a concentrate and the process will not be competitive until it will handle the middlings.

CCC thinks such a process is possible, so Sherrit and National Lead will stockpile middlings until the process is ready to use them.

FINISHED PRODUCT is a powder that can be pressed into forms for market. Copper powder can be extruded as rods.

Atomic Waste Will Lower Cost of Radiography

A SURVEY CONDUCTED at the Stanford Research Institute for the Atomic Energy Commission reveals that the use of atomic waste products will permit industrial radiography of a wide range of metals and metal products at greatly reduced costs.

Results of the survey indicate that certain by-products of the atomic pile, now waste, can be recovered and utilized for radiographic inspection at a cost substantially lower than present methods. In addition, radio-active fission products used in conjunction with Geiger counters and suitable film will be able to measure and control a number of industrial processes.

The availability of fission products at low cost would open up the whole field of radiography, both non-destructive and medical. The advantages of using fission products include: low cost, availability, and different energy levels obtainable in comparison with present sources.

The study shows that huge quantities of fission products can be made available to industry at relatively low cost, compared to present limited and expensive sources of radioactivity. A gram of radium, giving one curie of radiation, today costs $15,000 to $20,000. One curie of radiation from fission products will probably cost between a few cents and a few dollars, depending on the terms on which the Atomic Energy Commission will make them available, the cost of processing, and the extent to which they are utilized by industry.

In addition to their application to radiography and the operation of control instruments, fission products, according to the Stanford survey, have a number of other valuable industrial applications. They appear to be useful in food and drug sterilization, for eliminating static electricity in certain manufacturing processes, improving engine performance and making possible the development of a number of new chemical synthetics.

Plastic Sheath Protects Cylindrical Parts

AMSTERDAM—A thin-walled, pliable tube of polyvinyl chloride is being manufactured by N. V. Draka to protect parts like metal tubes and bars against moisture and chemicals.

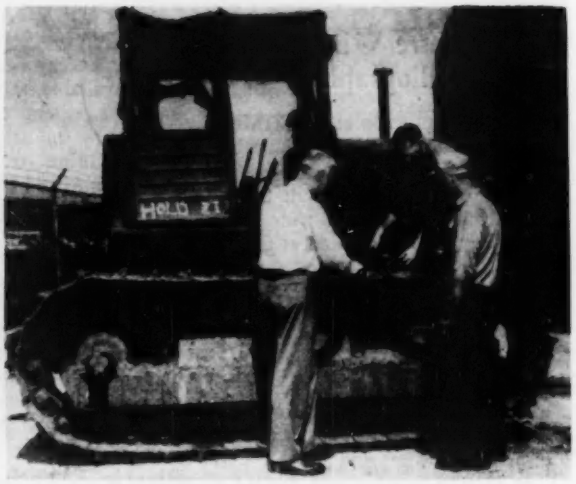
The plastic coat is applied by drawing the hose of polyvinyl chloride over a tube or bar. This hose is then heated to 115 C, at which point it shrinks and forms a tight enclosure for the bar in a few minutes. The deformation of the plastic is permanent.

This coating can also be used for steering wheels, vacuum cleaner handles, bannisters, door knobs, etc. Since polyvinyl chloride is resistant to a great number of chemicals, the new protective coating is suitable for the chemical and food industry. As an insulator it can also be used to protect personnel against contact with live electrical parts such as contact points, switch rods, handles, etc.

S. L. CRAWSHAW, Assistant to the President of the Western Gear Works, was elected President of the American Gear Manufacturers Association at its 36th Annual Meeting. A native of Pennsylvania who has spent his entire business career in the gearing industry, he is the author of numerous articles on gear engineering and applications. Mr. Crawshaw has been active in AGMA for many years, as a member of or chairman of engineering and administrative committees.

WORLD'S BIGGEST HELICOPTER, the XH-17, is powered by General Electric turbojets that supply gas pressure through ducts leading up the rotor shaft and out to the tips of the long rotor blades. To be used for short range moving of heavy military equipment like artillery, tanks, bridge sections, and trucks, it straddles its cargo like a lumber lift and picks up loads by attachments to landing gear and body. The whirley-bird is undergoing tied-down ground testing at Howard Hughes' Culver City California aircraft plant. Ground testing is scheduled to continue for several months before the helicopter is flight tested.

U. S. ARMY CATERPILLAR D-7 tractor is standard equipment for engineer units in road building and dirt moving operations.



RUSSIAN STALINETZ 80, captured in Korea, was copied from D-7's obtained by Russia under Lend Lease ten years ago.

Russians Copy U. S. Tractor Design

WHEN UN FORCES captured two battered Stalinetz 80 tractors in Korea, U. S. Army engineers were so struck by the similarity to their own Caterpillar D-7's that they asked the Caterpillar Tractor Company to study the captured models. Investigation showed that they were copies of the D-7 and revealed these facts:

1) The Reds redesigned the machines to fit more convenient metric dimensions.

2) Appearance was unimportant to the Russians. Parts are rough on the outside, but carefully machined where finishes and close tolerances are required.

3) Although raw materials available differ slightly, metallurgy on the Red copy is excellent.

4) The tractors probably were produced on an assembly line basis similar to that at Caterpillar.

Caterpillar's research director, J. M. Davies said: "The machines were a great surprise to us. They are of much better quality than we had expected."

In discussing the metric dimensioning, he added, "Considering all the parts which had to be changed and all the tolerances and fits of each of these parts had to be changed to metric standards, this is an achievement reflecting no slight engineering skill."

An indication that the Reds are concentrating on interchangeable parts was shown by the fact that the Russian Diesel engines tested at Caterpillar were assembled from parts of 2 separate tractor engines.

Metallurgists feel that the captured tractors reveal metallurgical techniques that American industry would have adopted if the same materials were available. Apparently, the Russians know where to make parts hard and where to make them tough, since hardness and toughness of parts is about the same as that used on American machines.

Caterpillar engineers believe that the Stalinetz 80 was copied from D-7 tractors obtained by Russia under Lend Lease about 10 years ago. They also believe that the machines would give satisfactory operation for such tasks as pulling military equipment and supplies in Korea.

RDB Tries to Figure Research Worker Costs

WASHINGTON—Preliminary compilation of data by the Research and Development Board of the Defense Department indicates that it is possible to establish standards for the cost per research worker and per research engineer and scientist.

These costs, when divided into proposed budgets, provide approximations of the manpower needed for the planned programs. RDB figures show that it costs industry an average of $20,100 to "keep" an engineer or scientist at work, and that the average annual cost of research workers (including all supporting personnel) is $8,500.

The standard costs were developed from data on all or a portion of the activities of 149 organizations (42 industrial firms, 51 universities and non-profit institutions, and 56 Federal Government research facilities), employing approximately 30 percent of the nation's research engineers and scientists.

Since there are wide differences in the cost per research worker and per engineer and scientist among the various laboratories, the data thus far collected are more valid when applied to broad programs than to specific situations because:

1) Accounting procedures vary widely among industry, university and Government and within each of these groups.

2) Differences in the ratio of engineers and scientists to total research workers result in wide variations in the cost per engineer and scientist. For example, in private industry more than 40 percent of the research workers are engineers and scientists, while in the Federal Government this ratio is only 25 percent.

3) Costs per research worker and per engineer and scientist vary with the particular phase of development.

4) Costs vary with the field of research.

New information on research manpower and costs is being collected by the Research and Development Board.

This data will make it possible for the first time to determine the average expenditures per research engineer and scientist and per research worker in various size research organizations in each of some 40 industries.

NRL Develops Quartz Paper

WASHINGTON—Chemists at the Naval Research Laboratory have succeeded in making a quartz paper that is superior to asbestos as an electrical insulating material.

Identical to quartz found in nature, laboratory-produced fibers are made into a paper in the same manner as ordinary writing paper. However, the quartz material has high temperature resistance and low electrical losses at high frequencies. It will withstand up to 3,000 F compared to a top limit of 1,000 F for asbestos.

Another valuable property is its low dielectric constant.

In contrast to other synthetic materials used for similar purposes, this paper does not contain boron; a property that makes it useful near radioactive substances since boron-containing materials become radioactive upon exposure to atomic radiation.

Navy scientists anticipate that the material will be useful as insulation in nuclear power plants.

New Pulse Transformer Responds in 0.02 Microseconds

A PULSE TRANSFORMER developed at the National Bureau of Standards produces a pulse rise from zero to 90 volts in less than 0.02 microseconds in a conventional blocking oscillator circuit. The new transformer is simple and inexpensive, and consists of a few turns of wire wound around a ferrite ring.

Blocking oscillators are transformer-coupled feedback oscillators designed to produce a single rectangular voltage when triggered by an actuating voltage. The more rapidly the pulse rises, the more accurately it can be associated with a particular instant of time. Some applications, like triggering, switching, and timing functions in radar equipment, require that the pulse also be of short duration.

Key to the quick acting of the new transformer is the ferrite core. Less than one inch in diameter, the core is made by cementing together two standard toroids of a commercially available ferrite. The plate, grid, and output windings consist of 13, 12 and 6 turns respectively of No. 24 enameled copper wires. Plate and grid windings are wound together in a single layer.

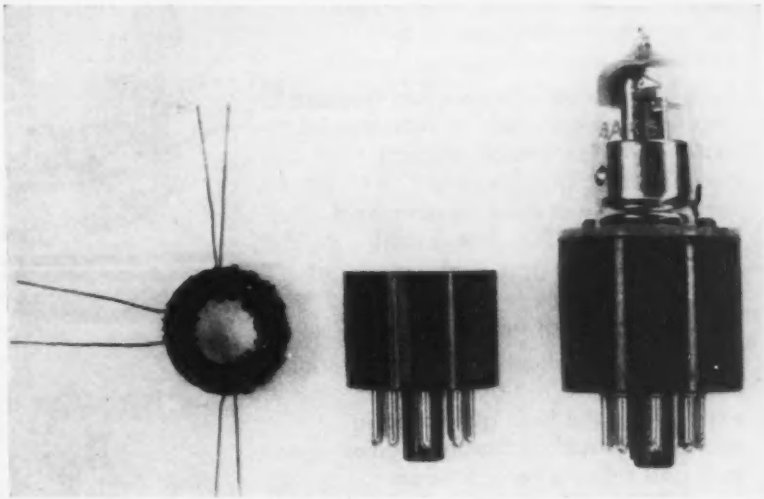
The small size of the transformers make it possible to construct a complete blocking oscillator as compact plug-in unit. One such unit being built at NBS consists of a transformer, a miniature tube, a grid capacitor and resistor mounted on an octal base. All leads are brought out to base pins, allowing for a variety of triggering and biasing methods.

Pulse characteristics of the new transformers in a conventional blocking oscillator circuit with a 500-ohm load were measured on a commercial oscilliscope designed for a fast sweep. Recovery time of the blocking oscillator is roughly three times as fast as that of previous units. Characteristics of this circuit are listed in Table I.

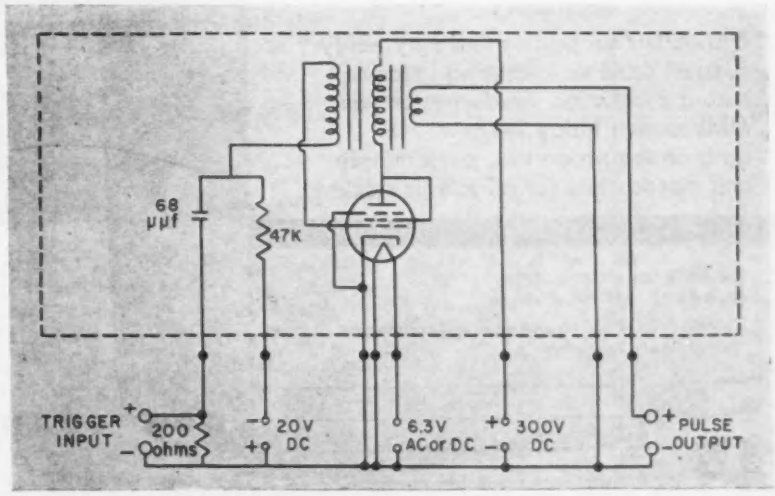
Table I—Pulse Characteristics

Pulse width *	less than 0.06 microsecond
Rise time	less than 0.02 microsecond
Pulse amplitude	90 v.
Output Impedance	100 ohms
Peak pulse power	20 watts
Recovery time (Blocking oscillator with 47 unf and 3,300 ohms in the grid circuit)	0.03 microseconds

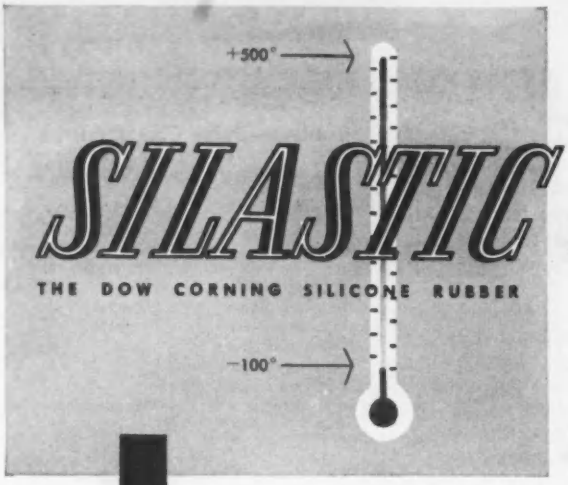
* Width of 0.03 microseconds can be obtained by using fewer transformer turns, but at the expense of reduced pulse amplitude.



FERRITE CORE PULSE TRANSFORMER (left) makes possible a compact blocking oscillator with a fast voltage pulse rise. Transformer fits into a plug-in base housing (center) so that a complete oscillator is made in plug-in form (right). Component is useful for triggering, switching and timing functions in electronic gear.



BLOCKING OSCILLATOR CIRCUIT like this uses pulse transformer. Elements inside the dotted line are incorporated into plug-in oscillator unit described above.



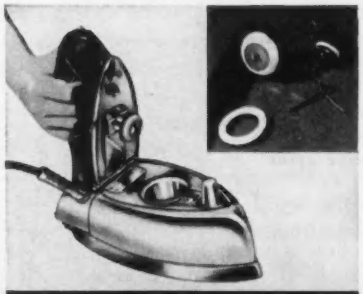
SILASTIC* stays elastic ...in oven heat or arctic cold

Here are just three examples of how Silastic is being used to improve products and to cut production and maintenance costs.

Such applications are practical because Silastic is the only kind of rubbery material that retains its physical and dielectric properties at temperature extremes ranging from —100° to over 500°F. It is most serviceable as a gasketing material at both high and low temperatures and in contact with hot oil.

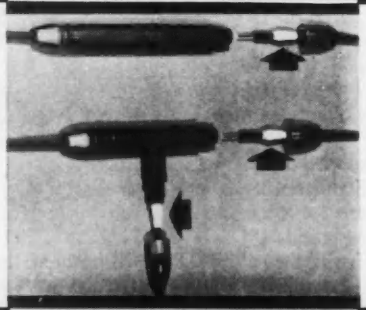
It is the only resilient insulating material that is not damaged by long exposure to the heat generated in overloaded traction motors. It gives long and reliable service as an insulating material for Navy control cable and for ignition cable in aircraft and ordnance vehicles. Silastic also repels water, and shows remarkable resistance to oxidation and to outdoor weathering.

Silastic has properties that may easily suggest some sales-making ideas or cure a production headache for you. Mail coupon today for new data on the properties, performance and applications for all Silastic stocks.



Silastic seals and gaskets are used to seal steam chambers in domestic steam irons because Silastic is insoluble in water, odorless, stainless and resilient at operating temperatures ranging up to 500°F. Life testing and field experience indicate that Silastic seals will retain their resilience for the normal service life of the iron.

Photo courtesy Rival Manufacturing Co.



All connections in aircraft antennae used to be individually spliced and taped. That tedious task has been eliminated, and static and corona discharge have been reduced by as much as 90% through the use of "Anstat" fittings equipped with Silastic seals. These seals retain their dielectric properties and exclude moisture and dust after long exposure to outdoor weathering and to the full range of ground and stratospheric temperatures.

Photo courtesy Fredric Flader, Inc.

Silastic pads and rollers are frequently used to apply pressure in heat sealing equipment. In this machine, for example, a Silastic ring is used to band cosmetic containers with a ribbon of gold leaf. It remains resilient and nonadhesive after long periods of service at surface temperatures above 400°F.

Photo courtesy Eldon Manufacturing Co.

DOW CORNING CORPORATION
Dept. No. R-19, Midland, Michigan

☐ Silastic Facts No. 10 on properties and performance.
☐ List of Silastic Fabricators.

Name_____
Title_____
Company_____
Address_____
City_____ Zone____ State_____

*T. M. Reg. U.S. Patent Office

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MIDLAND, MICHIGAN

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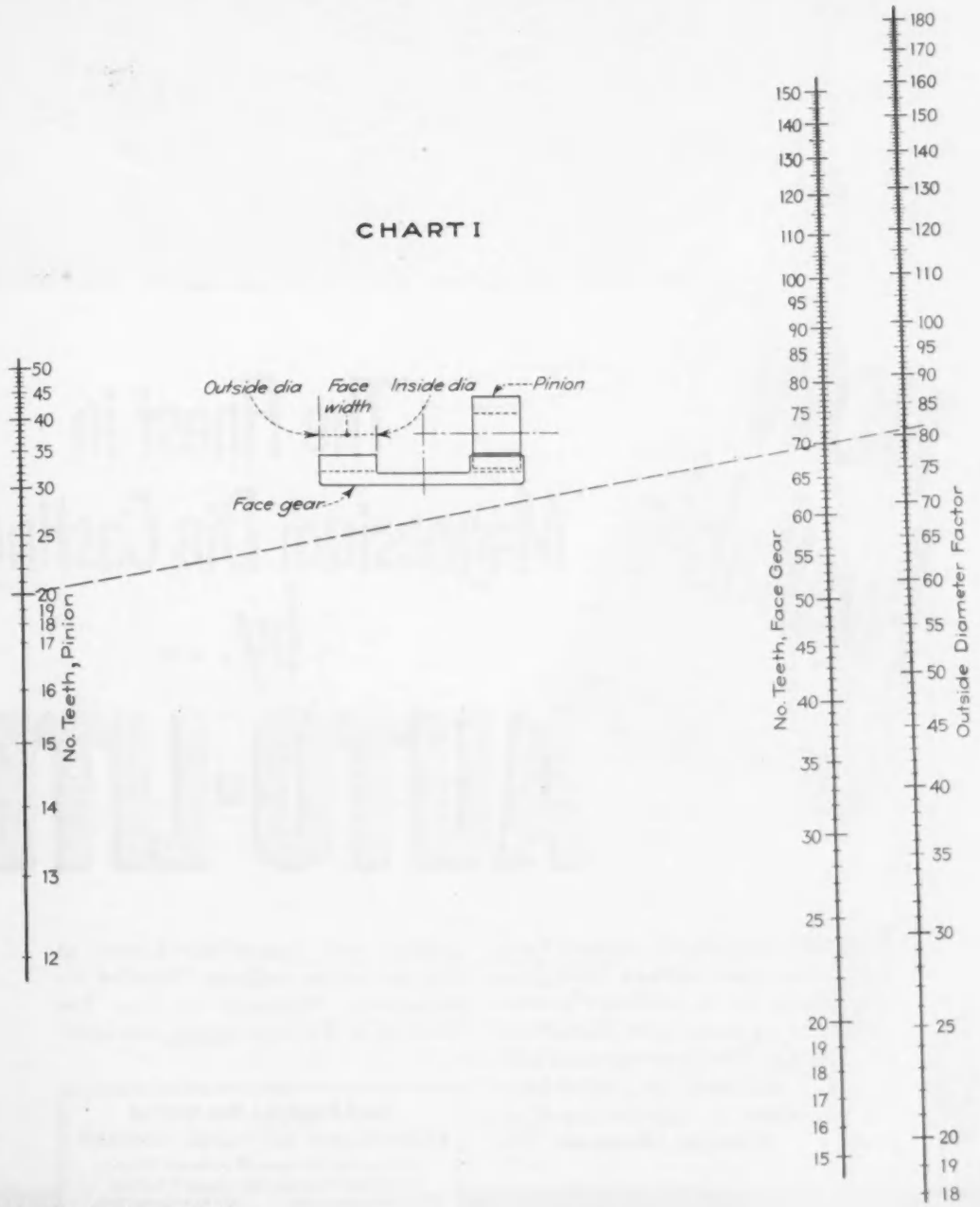
Alignment Chart for Face Gears

B. Bloomfield
The Fellows Gear Shaper Co.

THE MAXIMUM PRACTICAL DIAMETER for face gears is that diameter at which the teeth become pointed. The limiting inside diameter is the value at which tooth trimming occurs. This is always larger than the diameter for which the operating pressure angle is zero. The two alignment charts that follow can be used to find the maximum OD and the minimum ID if the numbers of teeth in the face gear and pinion are known. They eliminate lengthy calculations.

CHART I



(continued on page 191)

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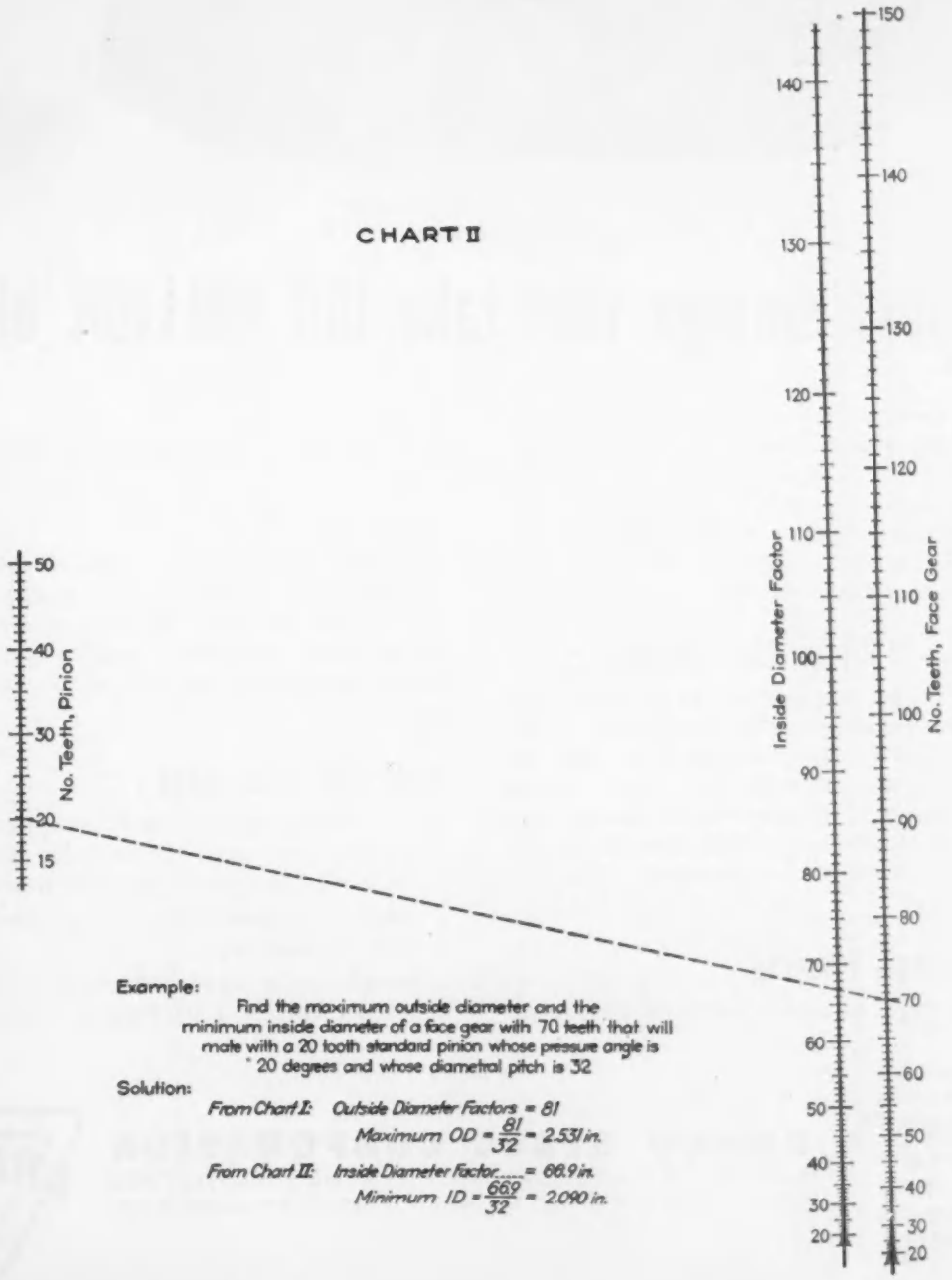
Alignment Chart for Face Gears (continued)

FOR BOTH CHARTS the pinions are assumed to be spur gears of standard AGMA proportions, and the axes of the face gear and pinion are assumed to intersect at right angles. Both should be used only for tooth ratios of 1.5 to 1 or larger. Smaller ratios require pinion modifications not allowed for in these data. For both charts, the appropriate face gear diameter is found by dividing the factor from the chart by the diametral pitch of the pinion.



Example:

Find the maximum outside diameter and the minimum inside diameter of a face gear with 70 teeth that will mate with a 20 tooth standard pinion whose pressure angle is 20 degrees and whose diametral pitch is 32

Solution:

From Chart I: *Outside Diameter Factors = 81*

Maximum OD $= \frac{81}{32} = 2.531$ *in.*

From Chart II: *Inside Diameter Factor* $= 66.9$ *in.*

Minimum ID $= \frac{66.9}{32} = 2.090$ *in.*

Stainless springs that take 100 MILLION blows!

These miniature precision switches are built to close and open as many as 100 million times—without a miss. Steel that takes an early permanent set cannot be used in the actuators of these switches. Operating clearances are often critically small and even a slight change in the position of the actuator may make the switch useless.

Armco 17-7 PH is the answer

Armco 17-7 PH Stainless Steel flat wire has solved major problems in these switches. Drift characteristics of this spring steel have been found superior to any other material tested. In addition, switch-life has been increased many times because of the great flexure endurance of the metal. Armco 17-7 PH is also highly corrosion resistant —another reason why it is used instead of ordinary carbon spring steel.

Takes severe forming

For the odd shapes required in switch actuators, Armco 17-7 PH can be cold formed without breaking. Its remarkable mechanical properties are then developed after fabrication through a low-temperature heat treatment at 900 F for 30 minutes.

Actuators made of standard types of stainless steels, soft enough to form properly, have poor spring characteristics. They will take a permanent set after relatively few operations. And standard stainless steels with good spring characteristics will crack or fracture if severely worked.

What the user says

The manufacturer of these switches uses Armco 17-7 PH in flat wire in more than 125 leaf spring designs.

This is what his engineers say about Armco 17-7 PH:

"There is no substitute known to us should this material not be available."

If you have a spring problem you will want to know more about Armco 17-7 PH. Write us for complete data.

ARMCO STEEL CORPORATION

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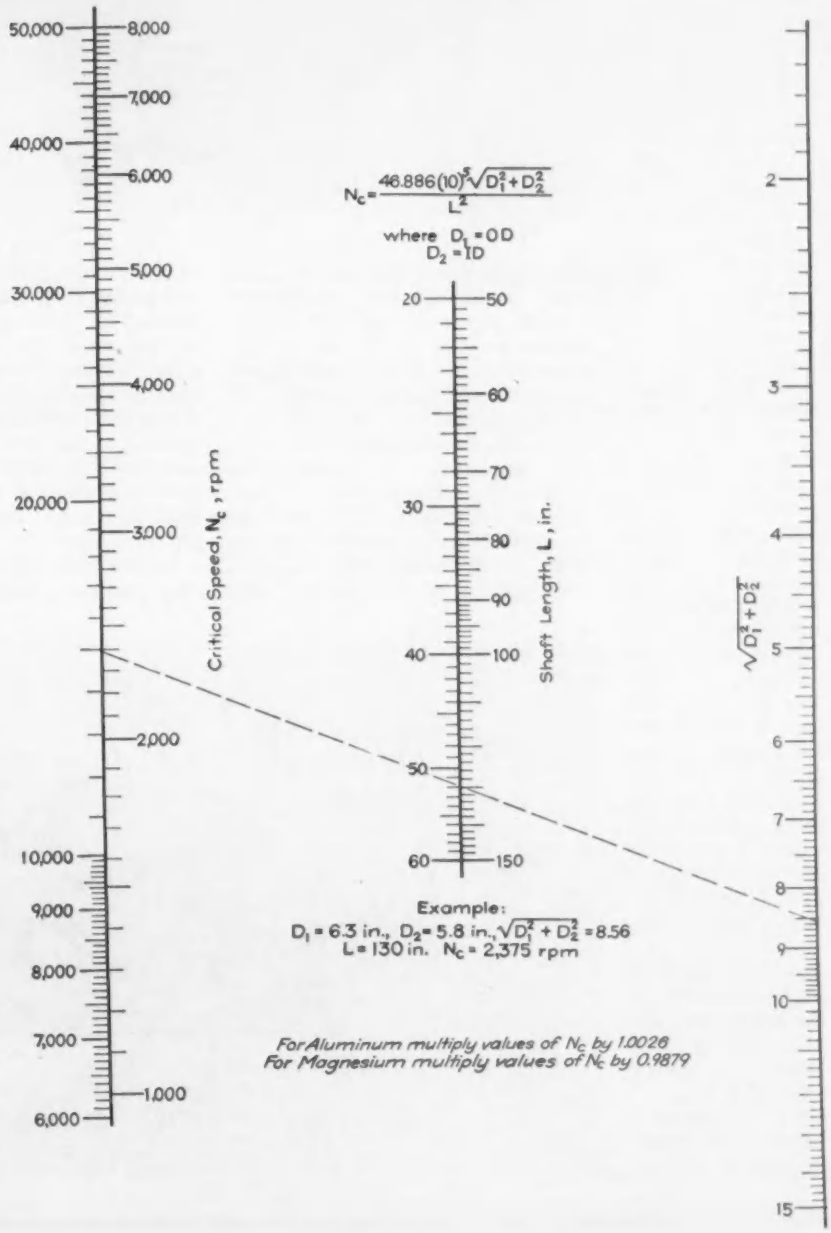
ARMCO

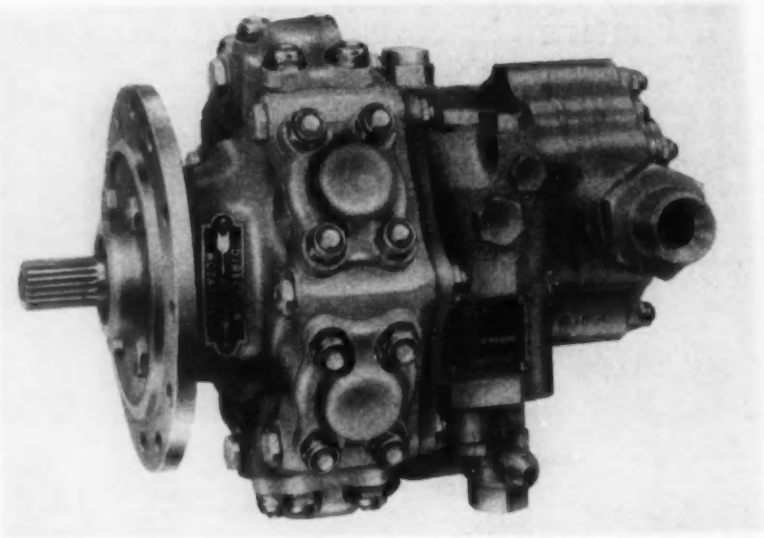
Critical Speeds of End Supported, Bare Shafts

L. MORGAN PORTER
Pratt & Whitney Aircraft

THIS NOMOGRAM solves the equation for the critical speed of a bare steel shaft that is hinged at the bearings. For one bearing fixed and the other hinged multiply the critical speed by 1.56. For both bearings fixed, multiply the critical speed by 2.27. The scales for critical speed and length of shaft between bearings have been folded to cover a greater range. Thus the right hand sides of both scales must be used together, or the left sides of both scales can be used.



Completely Automatic Hydraulic Pump



Though designed for aircraft use, this Vardel hydraulic pump maintains pressures up to 4,000 psi with a delivery of 5 gpm at 3,000 rpm, and is suited for industrial uses where a completely automatic pump is required. The pump weighs only 13¼ lb, and has its own cut-out and relief valves with delivery automatically stopping when the set pressure is reached.

The Vardel is a two stage pump. The first stage is a conventional type gear pump of light construction with the driver gear coupled to an extension of a second stage drive shaft. The output from the gear pump exceeds the capacity of the second stage pump, with the excess being recirculated through a pressure relief valve to give a steady pressure in the first stage circuit. The main volume is delivered through a control valve to the inlet of the high pressure pump, which consists of seven radially positioned cylinders having pistons reciprocated by means of an eccentric shaft. Fluid from the inlet port enters each cylinder in turn from an annular passage and is pumped past non-return valves into the high pressure supply line.

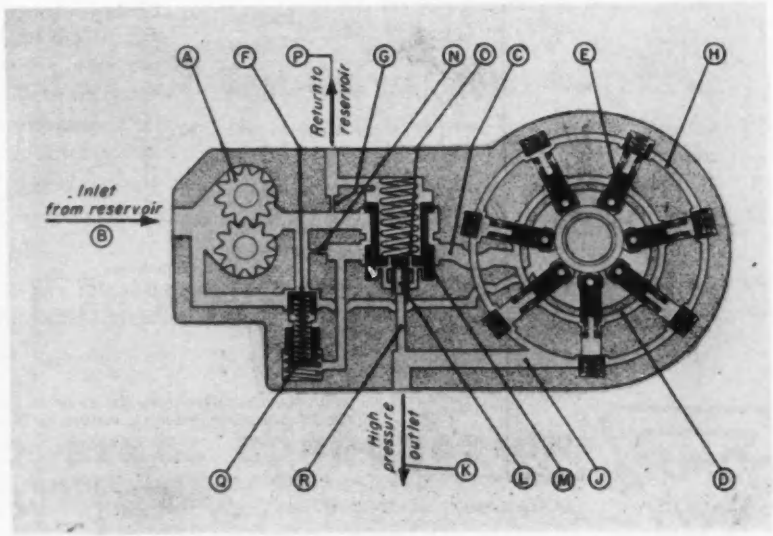
The sequence of operations is shown in the cross-sectional view. The first stage pump A draws fluid from the reservoir through inlet B and delivers it at low pressure via passage C to the inlet annulus D of the second stage pump E. The excess output from the gear pump is recirculated through the relief valve F. A limited quantity is pumped back to reservoir, through a restricted orifice G in order to maintain uniform temperature and viscosity of the fluid.

The piston pump delivers fluid at high pressures through the annulus H and passage J to the pump outlet K. The oilway R transmits the high pressure to piston L which acts against the spring load on the valve M.

At maximum pressure the piston L overcomes the resistance of the spring and causes the slide valve M to seal off the main supply from the first stage pump. A limited flow is maintained through the small orifice N which reaches the inlet of the second stage pump through a by-pass annulus and passage C. This flow is pumped into the high pressure circuit until maximum pressure is attained. This occurs when the piston L has moved inwards a sufficient distance to uncover escape ports from channel R. Through these the fluid returns to reservoir by way of the spring housing and passage P.

The idling of the piston pump creates strong suction in the annulus D and passages communicating with the housing of piston Q. The reduction of pressure on the underside of the piston increases the effect of the pressures acting above it. The resultant downward movement enlarges the opening of the relief valve port. The main volume from the gear pump then recirculates at a pressure lower than the normal "on load" setting of the relief valve.

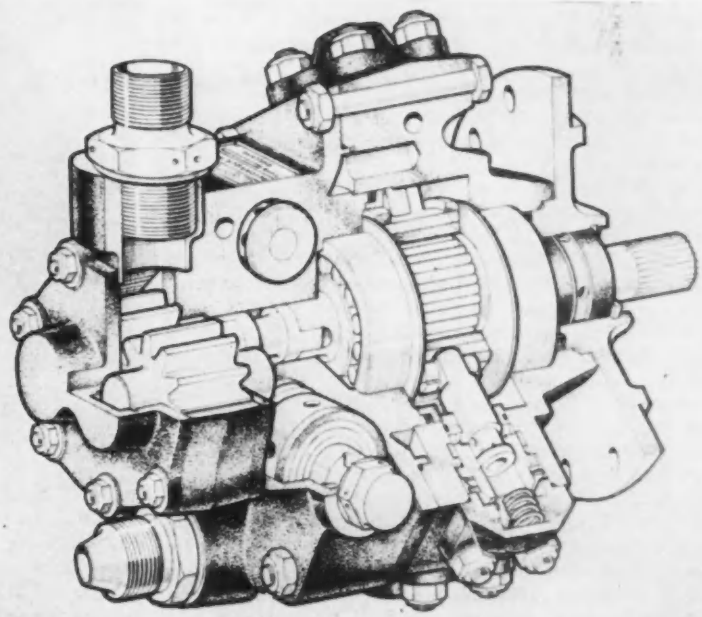
Known as the type 5050-Y, the two stage pump is a variable delivery unit

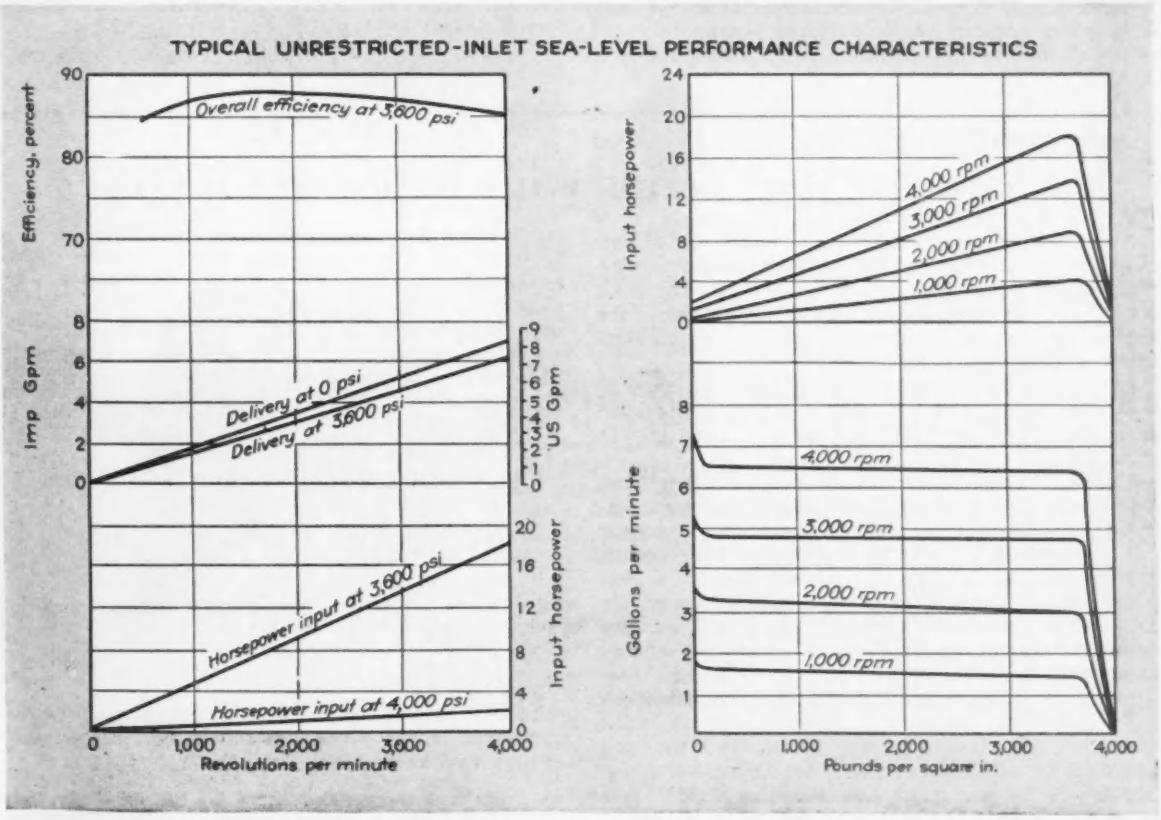


with no external control gear required. The pump mechanism provides a complete hydraulic power system which will adjust itself to the demands of the hydraulic units. Pumps are available with maximum pressures from 2,000 to 4,000 psi. At 3,000 rpm the nominal rate of delivery is 5 imperial, (6 U. S.) gal/min., with constant delivery maintained up to 90 percent of the maximum pressure, and decreasing to zero delivery at the full "off load" pressure.

The performance characteristics for the Model 5050-Y/4,000 at sea level are in the graph at left which shows that the maximum power requirements at 3,000 rpm and 4,000 lb/sq. in. is under 1 horsepower. The power load for full flow is less than 14 hp giving efficiency greater than 85 percent. Higher efficiencies are obtained in the pressure range that is most commonly used in operating hydraulic jacks.

Dowty Corp., 25 Beaver St., New York 4, N. Y.





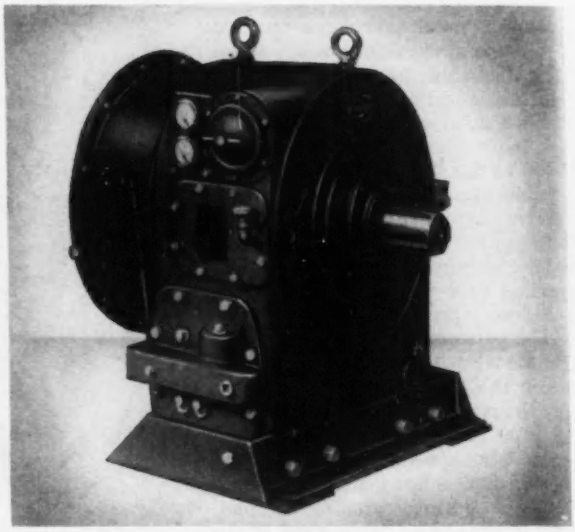
CONTINUED ON PAGE 196

Single-Stage, Three Element Torque Converter

Combining a hydraulic torque converter and hydraulic coupling in a single unit, the new model 17-K single stage, three element type unit is said to increase the efficiency over a wide range when used with locomotives, road machinery, rail cars, logging machinery, and lift trucks. This model can be used with gas or diesel engines rated up to 300 hp, and is equipped with roller bearings to give long life.

The converter has a variable torque ratio up to 3:1. At zero output speed, the torque multiplication is highest; this gradually decreases with increasing output speed until a point is reached where the output and input torque are equal. Because the engine performs at almost constant speed during the converter range, overload will not cause stalling. When the torque ratio reaches 1:1, the reaction member is free wheeled and the unit acts as a hydraulic coupling. In the coupling range, output speed increases in nearly direct proportion to engine speed.

Major elements of the converter consist of the converter pump, converter turbine, and reaction member. For continuous operating efficiency and ease of servicing, there are no close clearances in these elements, which are each single-piece aluminum castings. Piston-ring type oil seals, which contain the oil in the working elements, permit passage of a small amount of oil to provide continuous controlled bearing lubrication. This controlled leakage drains into the oil reservoir which is integral with the converter housing. The bearings are designed so that sprocket or gear drive can be attached to the output shaft without the necessity of an outboard bearing.



The chain-driven oil circulating pump is mounted on a base plate for easy accessibility and inspection. The converter uses standard SAE No. 10 motor oil, and has built-in oil filter, temperature, and pressure gages. It can be modified to meet the specific requirements of individual applications. The converters are supplied as a unit package, and are constructed for ease of installation and service. Special designs are available.

The Torcon Corp., 1179 West Fifth St., Ashtabula, Ohio

Precision Gear Trains with Ratios to 15,000:1

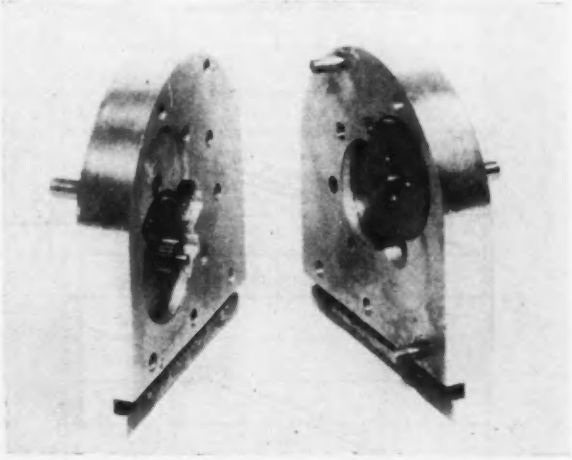
Available in ratios up to 15,000:1, a new line of precision gear trains for instrument applications are being made in the same general case dimensions. The shaft height from the mounting surface and shaft diameter are standard for use with conventional laboratory servomechanisms breadboards and components.

For applications where various reductions are required at different times, the gear train is available with a modified design that will incorporate a variety of internal gearing arrangements.

Maximum output torque for low shaft speeds is about 5 foot-pounds. Where stops are used in the system, or sudden high loads are possible, the manufacturers suggest that the gear train be used with a slip clutch. Unless otherwise specified, the backlash is held to less than 0.2 degree.

The inertia is dependent upon the ratio required. In cases where inertia is of particular importance, the first mating gear may be lightened in mass. Steel gears are used because of their better wear characteristics. Lighter, nonferrous gears are not recommended by the manufacturer.

A standard base mounting is shown on the unit in the illustration. Face mounting may be provided for most electro-mechanical components on either the input or output face side of the gear train. Known as the No. 107 gear



trains, they are designed for laboratory use and not for wide temperature ranges. Extra gear clusters of different ratio are supplied to be used in the same housing.

Bowmar Instrument Corp., 4214 Leo Rd., Ft. Wayne, Ind.

CONTINUED ON PAGE 198

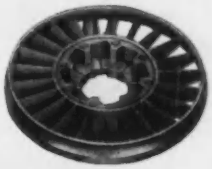
creative castings

Motor End Frames

Gyrol Fluid Coupling

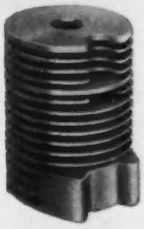
Garbage Disposer Housing

Aircraft Piston



Torque Converter

Fuel Pump Body



Carbon Pile Regulator

Steel-Belted Piston

Alternator Housing

Diesel Permanent Mold Piston

Wing Actuator

Air Connector

Launching Barrel for Bazooka

For many years the foundry of Thompson's Light Metals Division quietly cast thousands and thousands of hard-to-make precision parts in light alloys of aluminum and magnesium.

Word got around that Thompson had the experience and facilities to cast light-weight, strong, heat-resisting alloy parts in permanent molds and high pressure dies—which eliminated the weight problems of ferrous counterparts. One by one manufacturers came to Thompson for help and advice when they learned that the close tolerances achieved by Thompson cut machining and finishing costs.

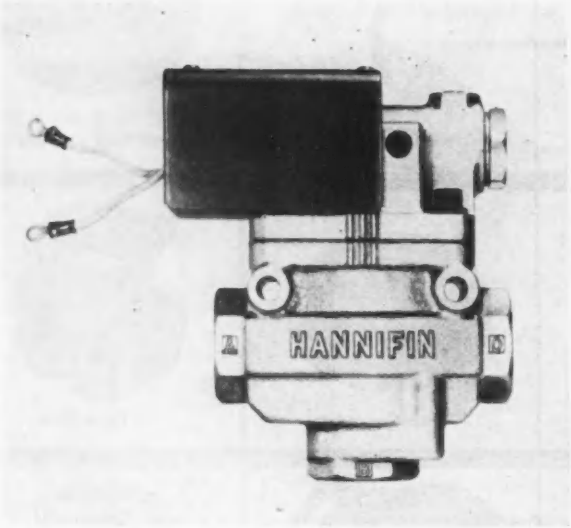
Today, our capacity is channeled to top-rated jobs. We're building additional facilities as fast as possible and, in the meantime, Thompson services, as always, are at your command. Our entire staff of creative engineers is ready to help you plan new parts or re-design old ones for the future.

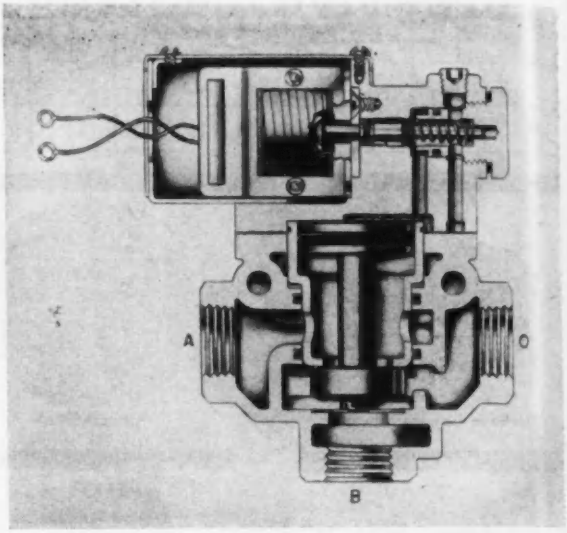
A THOMPSON STORY TOO BIG TO HIDE!

Thompson Products, Inc.

2269 Ashland Road • Cleveland 3, Ohio

LIGHT METALS DIVISION





Valve May Be Operated Either 2 or 3-Way

The main or master valve portion of a new pilot-master valve can be operated either 2-way or 3-way, normally open to pressure, or normally closed to pressure, without any internal change. This is possible because of the interchangeability of the inlet and exhaust ports. Port A, at the left in the illustration, is the inlet for normally closed operation, and an exhaust port for normally open use, Port B, at the bottom, is the inlet for normally open use, and the exhaust for normally closed. By inserting a pipe plug in the exhaust port, either A or B, converts the valve for 2-way use. Port O, at the right, is the outlet in any case, normally to an air cylinder.

The main valve is pressure operated, through a piston-operated poppet. Since pressure acts both to actuate the poppet and to return it to its normal position, the main valve is completely springless, which eliminates a source of valve failure. Maintenance is also reduced because the piston-poppet assembly, the only moving part of the main valve, fits in a removable cartridge which acts both as the cylinder for the piston and as the upper seat for the poppet. This cartridge can be removed and replaced by removing the cover, in this case, the pilot head, without disturbing any of the main piping connections. Only two sizes of cartridge-and-piston-poppet assemblies are needed to service all five main valve bodies from $\frac{3}{8}$ in. through $1\frac{1}{4}$ in. IPS.

In addition, one size of pilot head fits all five sizes of master valve in the pilot-master combination. Within the pilot head is a 3-way pilot valve, solenoid operated, which controls the main valve by introducing pressure into, or exhausting it from, the chamber above the piston. Pressure within the pilot valve is normally taken from the pressure side of the master valve, and exhausted to the exhaust side of the master valve, but pilot pressure from another source can be used. As shown in the cross-section view, the pilot valve also is a poppet valve, the stem of which is actuated by the plunger of the solenoid, and returned by a lightly stressed stainless steel spring. Only four moving parts, the poppet stem, spring and O ring and the solenoid plunger, are involved. A second O ring acts as a resilient seal when the poppet contacts either seat, and is replaced with the poppet stem. The solenoid is of industrial quality and can be completely disassembled, either to replace a burned out coil, or to install a coil of another voltage.

Full $\frac{1}{8}$ in. I.P.S. passages within the pilot valve, plus the short stroke of the pilot stem and the main piston-poppet, give almost instant valve action. On 60 cycle current this pilot master valve will shift in less than 1/20 of a second. The valve can also be supplied with d-c solenoid. The pressure range is from 15 to 150 psi with air or gas, with higher pressures possible with water or oil.

Hannifin Corp., 1126 S. Kilbourn Ave., Chicago 24, Ill.

Protective Plastic Coating for Electronic Wiring

A new aircraft wire, developed to meet electronic wiring applications for military aircraft, features a polyvinyl chloride plastic primary insulation, and a nylon jacket extruded on wire. The wire meets all requirements of military specifications MIL-W-5274 A. Type I wire primary insulation must withstand 5000 v a-c at 60 cycles rms without failure. Type II wire primary insulation must take 12,000 v rms.

The polyvinyl chloride plastic primary covering, made from geon resin helps to give the wire resistance to cold weather (—54 C without cracking), oil, grease, fungus, abrasion, and flame. Vinyl is self-extinguishing when the source of flame is removed.

Surprenant Mfg. Co., Webster & Atlas Bank Bldg., Boston 8, Mass.

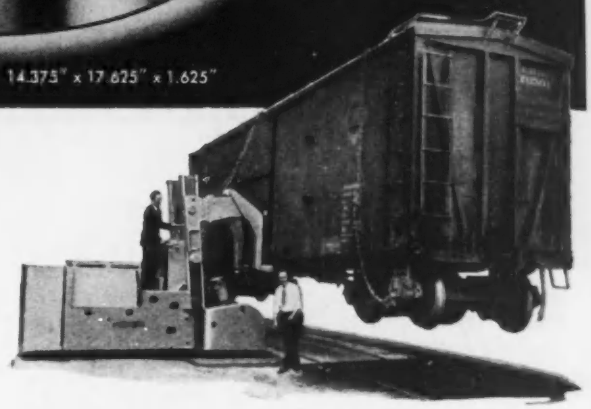
CONTINUED ON PAGE 200

Contact KAYDON of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER

Special KAYDON Ball Bearings: 14.375" x 17.625" x 1.625"

KAYDON-bearinged Lift Trucks pick up 30-ton freight cars



HUSKY KAYDON Special Ball Bearings . . . with static thrust capacity of 120,500 lbs. each . . . help Automatic Skylift Giant Electric Trucks lift multi-ton loads smoothly, efficiently. Made by Automatic Transportation Company, these KAYDON-bearinged trucks live up to their claim to "lighten life's loads." They shoulder heavy responsibilities without flinching!

The precision of these bearings is vital to the steering ease of these powerful lift trucks. They support the heavily loaded trail axle wheels, for steering ease. Diametrical ball clearance is closely held. These special ball bearings are typical of the unusual designs KAYDON engineers create to help machine designers achieve their objectives.

For dependable counsel on Precision Bearings and Needle Rollers, contact KAYDON of Muskegon.

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

THE KAYDON ENGINEERING CORP.

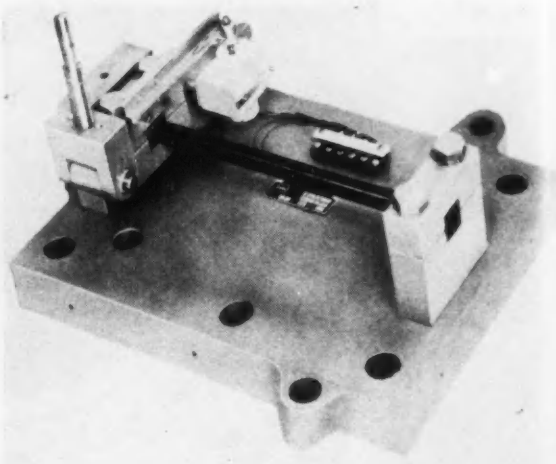
MUSKEGON • MICHIGAN

PRECISION BALL AND ROLLER BEARINGS

Sensitive Torsion Bar Load Cell

A new precision instrument, a torsion bar and load cell, designed to change a mechanical force into an electrical signal, consists of a differential transformer and a torsion bar which is held fast at one end and allowed to rotate on the opposite end. The free end connects to the force through a lever and when force is applied to the lever, the bar tends to rotate with the stresses set up in the bar resisting the twisting force. The armature of the transformer is also connected to the free end of the torsion bar through a lever and moves in the coil of the transformer when force is applied. Each armature position results in a generated electrical signal propositional to its position off center. This signal may be fed into a remotely located indicator or recorder for evaluation. To hold stresses on the bar to a minimum, movement on load screw is only 0.060 inch.

The torsion bar load cell has an accuracy of $\pm\frac{1}{4}$ percent of full load cell range and is sensitive to 3,000 measurable parts of full load capacity when used with a null-balance indicator or recorder system made by this company. It may be used for both tension and compression loads going through zero to full capacity in either direction or may be used in one direction only. Available in ranges from 0-100 to 0-2,500 lb, the load cell is said to have been successfully applied to dynamometers, input torque, output torque, and bolt ring torque on propeller hubs. For more information on this and other precision instruments write to the manufacturer.



Automatic Temperature Control Co., Inc.,
5200 *Pulaski Ave., Philadelphia* 44, *Pa.*

Successive Operations Automatically Controlled

The development of new sequence count controllers makes possible the automatic control of several successive operations by accurately counting the number of operations required for each phase.

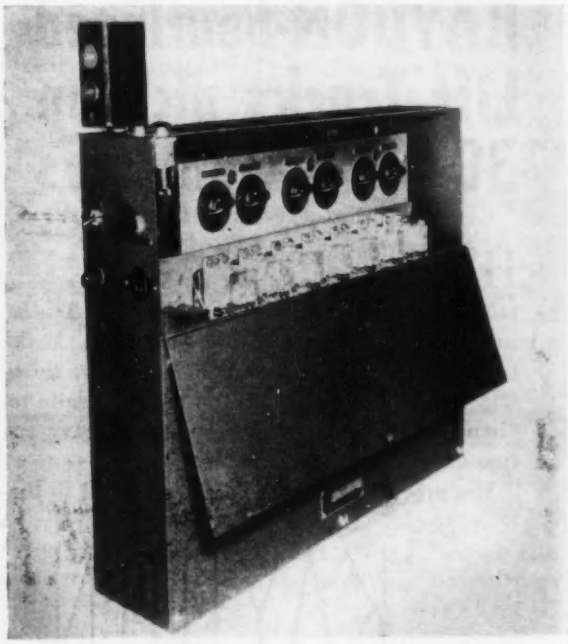
This new instrument automatically counts the pre-set quantity for the first stage, then operates a control switch which may be used to start the second phase, and automatically starts counting operations of the second stage.

It is used to control inter-related operations in machining and processing, to count different quantities of different items into containers, and to operate various types of automatic machines, such as stator winders.

As an illustration, in the automatic winding of motor stators, each pole requires a fixed number of turns in the first slot, another number in the second slot, and so on. In operating the automatic winder, the sequence count-controller counts the turns wound into the first slot, controls automatic repositioning of the stator; counts the required number of turns into the second slot, again repositioning the stator. When the proper number of turns is wound into the last slot, the controller causes the machine to position the stator for winding the next pole and the sequence is repeated.

Sequence count control can be used for almost any number of consecutive operations. Practically any quantity can be counted in each phase of operation with provisions made for the quick selection or change of count quantity.

The switch that comes on at completion of each phase count is adaptable to a wide range of control operations.



Production Instrument Co.,
702-10 *W. Jackson Blvd., Chicago* 6, *Ill.*

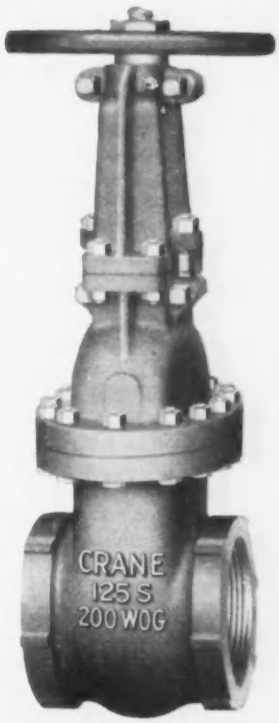
CONTINUED ON PAGE 202

Spend less time on piping specs . . .

See your CRANE Catalog first

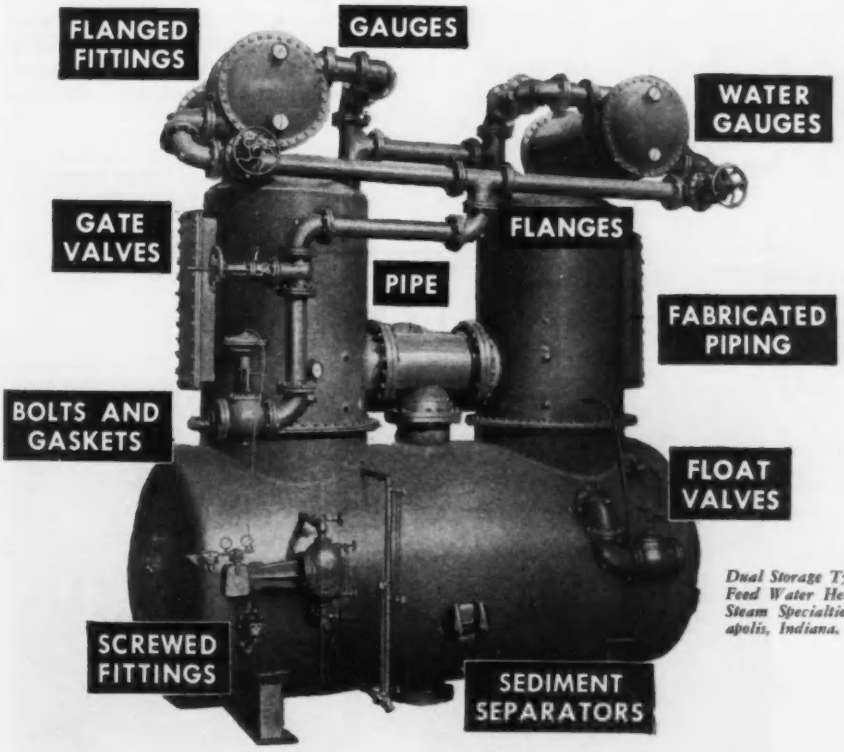
Yes, you'll spend less time on piping specs by going first to your Crane Catalog. Here's why: Crane offers the world's most complete selection of quality piping materials . . . there's rarely need to compromise or search elsewhere. Furthermore, with each item, Crane gives complete information including sizes and dimensions, tabulated pressure and temperature ratings, design, material and construction details—plus a run-down of recommended services. In addition, there's a wealth of general engineering data to help with your design problems.

But here's the real advantage to be gained in specifying Crane—your finished product will have an added value that's recognized by machinery buyers. From long experience, they know that "Crane equipped" means equipped for lasting service.



FOR ALL-ROUND SERVICE on steam, water, oil, or gas lines . . . Crane recommends 125-Pound Iron Body Wedge Gate Valves, brass trimmed or all-iron. Available in Non-Rising Stem, O. S. & Y., Underwriters', and Quick Opening patterns. Screwed, flanged, or hub ends. Sizes: 2-inch and larger.

FOR TOP QUALITY EVERY TIME . . .
DEPEND ON THE BROAD CRANE PIPING LINE



Dual Storage Type Deaerating Feed Water Heater by Stickle Steam Specialties Co., Indianapolis, Indiana.

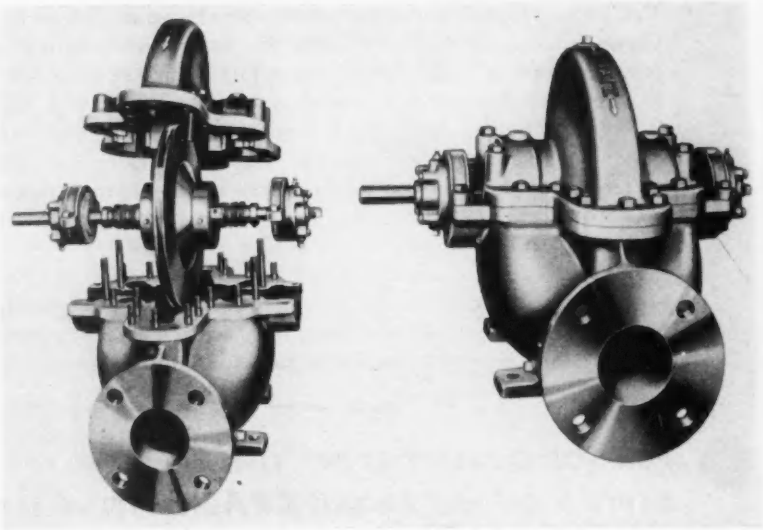
The Complete Crane Line Meets All Your Valve Needs. That's Why—
More Crane Valves Are Used Than Any Other Make!

CRANE VALVES

CRANE CO., *General Offices:* 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING

Increased Pump Efficiency With Shorter Shaft



Using standard mechanical shaft seals instead of the conventional stuffing boxes, resulting in savings in floor space, shorter shaft lengths, improved performance characteristics and easier pump servicing, are some of the features of a new line of horizontal, split-case, general service pumps.

This line of pumps, designated as the type AS, is available in discharge sizes from 1½ in. through 4 inches. Capacity range is up to 750 gpm and head range is up to 230 feet. General application is for pumping water and clear liquids up to 200 F.

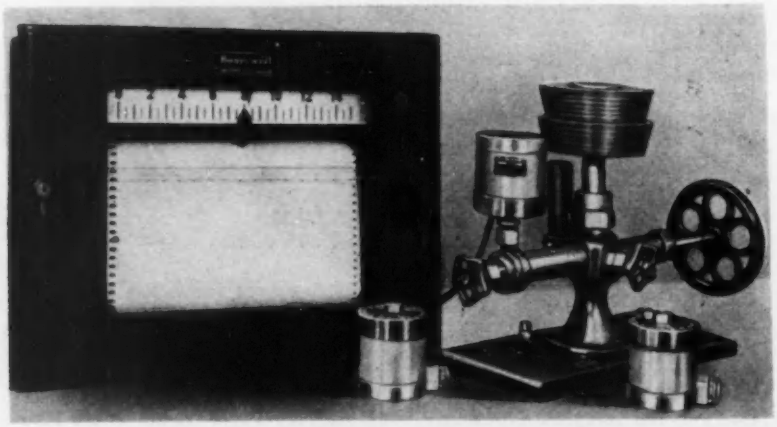
By use of standard mechanical shaft seals, instead af conventional stuffing boxes, the manufacturer claims that the pump shaft of the type AS pump is shortened to ½ the length of shafts in conventional pumps of the same size. As a result, the type AS shaft is said to be more rigid, and the shaft deflection materially reduced. The results are said to be in smoother, quieter operation and longer life for bearings, seals, and wearing surfaces. The seals used in this pump design are of standard manufacture.

By eliminating the stuffing boxes, and reducing the shaft length, the manufacturer claims that the new pump occupies ½ the floor space required by other types of general purpose pumps of the same capacity. It was also found to have a slightly higher efficiency, as compared size for size with the conventional pump.

Because of the split case design, the top half of the pump case may be removed and the rotating element lifted from the case without disturbing pump alignment or connections. All types of drives may be used.

Food Machinery and Chemical Corp., Peerless Pump Div.,
301 *West Ave.* 26, *Los Angeles* 31, *Calif.*

Remote Pressure Recorder and Control



Combined with an Electronik continuous balance potentiometer, the teledyne electrical pressure transmitter offers an accurate and convenient means for the recording and control of fluid and gas pressures. The teledyne, shown connected to a recorder, is a precision, strain gage type pressure transducer, and available in twelve standard ranges from 50 to 10,000 psi. The other teledyne units shown in the foreground are individually calibrated and tested, and supplied with a calibration curve. The units have negative hysteresis and are compensated for changes in sensitivity with temperature.

This packaged unit is especially adapted for remotely recording pressures either by direct wire or telemetering. The electronik recorder serves both as a source of voltage to excite the strain gage bridge of the teledyne unit, and as a medium for indicating and recording the electrical output of the unit. Therefore, there is no necessity for providing an external standard source of voltage for exciting the strain gage pickup with a stabilized low potential.

Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Wayne & Windrim Aves., Philadelphia 44, *Pa.*

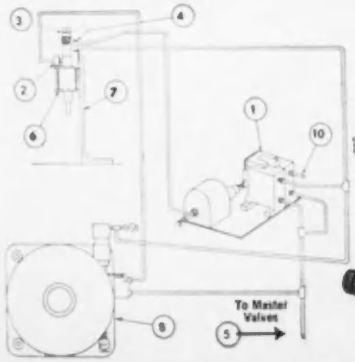
CONTINUED ON PAGE 204

PRESENTING THE AIR-OPERATED ROTARY WORK FEEDER IN ACTION!

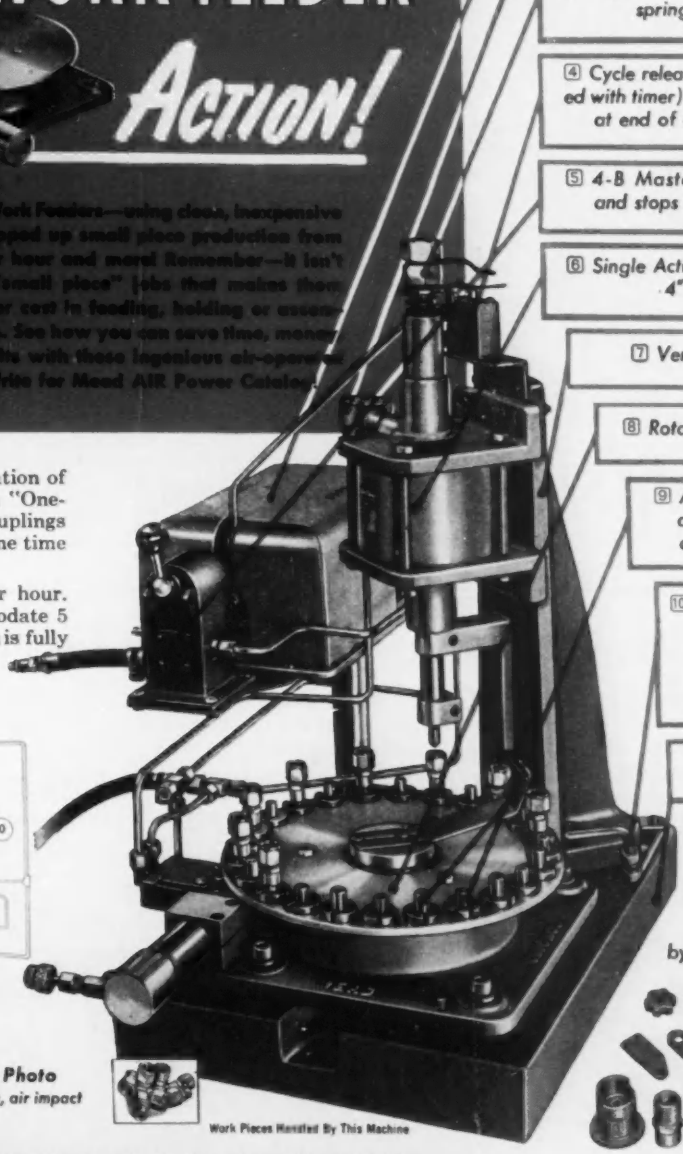
TIME and again Mead Work Feeders—using clean, inexpensive Air Power—have stepped up small piece production from 200 to 2,000 pieces per hour and more! Remember—it isn't the material in these "small piece" jobs that makes them expensive—it's the labor cost in feeding, holding or assembling them. Get the facts. See how you can save time, money, labor and increase profits with these ingenious air-operated MEAD Work Feeders. Write for Mead AIR Power Catalog.

A simple and inexpensive combination of Mead pneumatic devices makes a "One-Man Factory" to assemble brass couplings by flaring neck into nut, at the same time forming a fluid-tight seat.

Output approximately 2500 per hour. Two sets of 12 mandrels accommodate 5 different styles and sizes. Operation is fully automatic except for loading.



Circuit Diagram of Units in This Photo
Combine readily to feed work to drill press, air impact hammer for a wide variety of operations.



Work Pieces Handled By This Machine

1. Model 2 Meadmatic Timer
2. #2 Quick Exhaust Valve to speed up return stroke
3. Adjustable depth stop with spring return
4. Cycle release valve (included with timer) to reverse cycle at end of down stroke
5. 4-B Master Valve starts and stops entire system
6. Single Acting Cylinder, 4" bore
7. Vertical Stand
8. Rotary Work Feeder
9. Alternate mandrels for two sizes of brass couplings
10. Air blast ejection of finished parts, by jet piped from second of two valves in timer
11. Universal Base

Typical Work Pieces Handled by Mead work feeders

MEAD SPECIALTIES COMPANY, Dept. PE-72, 4114 No. Knox Ave., Chicago 41, Ill.

Memo Coupon

MEAD SPECIALTIES CO.
4114 N. Knox Ave., DEPT. PE-72, Chicago 41, Ill.
Send free copy of new, colored MEAD INDUSTRIAL AIR POWER CATALOG describing the complete line of famous Mead air-operated devices.

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City_____ Zone____ State_____

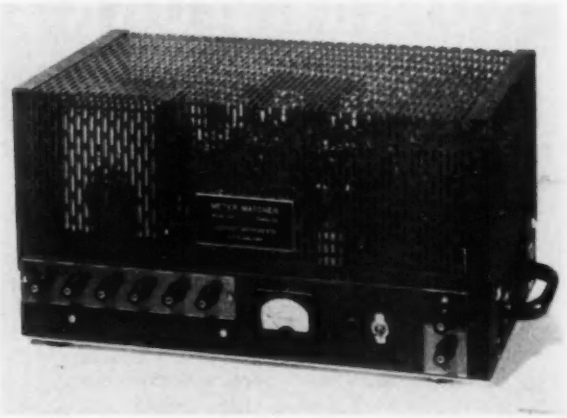
Amplifier Reduces Errors of Loaded Test Circuit

The model 105 Meter Master, an accurate power frequency amplifier that reduces the errors caused by the measuring instruments that load a test circuit, relieves a test circuit from supplying the usual power to the measuring voltmeter or wattmeter. Errors caused by the meter currents are practically eliminated.

The circuit to be tested is connected to the input of the meter master, and its output is connected to a voltmeter or the voltage coil of a wattmeter. The amplifier's input impedance requires a maximum of only 150 microamperes from the circuit being tested. Its output gives the 0.05 to 0.07 amp which most accurate dynamometer instruments require for full scale deflection. The meter current, which in some cases is larger than the normal circuit current, is eliminated from the circuit under test.

Input connections for 15, 75, 150, 300, and 600 v inputs are located in the front and in each case the output is 150 volts. This gives a 150-volt voltmeter or wattmeter an effective range of full scale voltages from 15 to 600 volts. Overall accuracy of the unit is such that less than 0.15 percent is added to measurements.

Applications of the amplifier include: measuring both linear and non-linear circuits when meter currents introduce errors not easily computed; giving a 150 v voltmeter or wattmeter voltage coil an effective full scale range of 15 to 600 volts; increasing meter sensitivities; and as a signal amplifier. The weight of the unit is about 30 pounds.



Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio

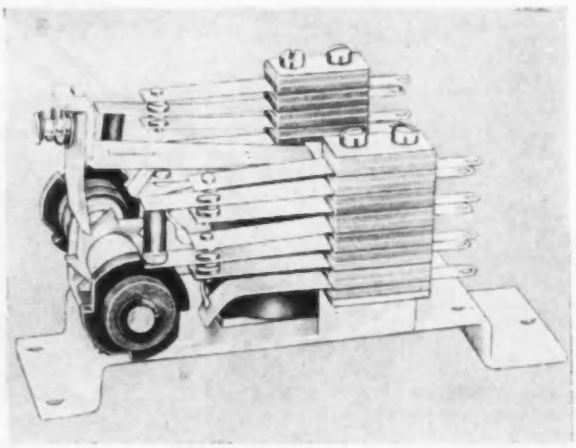
Impulse Ratchet Type Relay Has Automatic Stop

Featuring a new construction with an automatic stop to prevent slippage or overtravel of the ratchet, a new AP impulse, ratchet type relay is said to give positive, precise action on each impulse, regardless of the speed of operation. The relay is capable of high speed operation with a contact transfer time as short as 20 milliseconds.

Standard AP relays are available up to 230 v, either a-c or d-c, and with contact combinations up to 4-pole double throw, (4 Form C). Contacts are 3/16 in. dia fine silver, and rated at 5 amp, 115 v a-c, non-inductive load.

The coils are random wound on molded bakelite bobbins. Minimum breakdown of 500 v rms to core and frame. The entire assembly is compact, with phenolic cams, a hardened steel ratchet and pawl, and pin-hinged armatures.

The standard model with balanced armature construction measures 2⅛ in. wide, by 4 in. long, by 2⅛ in. high.



Potter & Brumfield, Princeton, Indiana

Pipe Fittings Lined With Reinforced Plastic

For acid work, and where corrosion or contamination should not take place, valves, piping, and other equipment of fully-vitrified solid white porcelain are now available with reinforced plastic armor. This armor is applied in the form of multiple layers of heavy fiberglass woven cloth, impregnated with a modified phenolic resin of high adhesive strength for bonding to porcelain, and between layers of cloth.

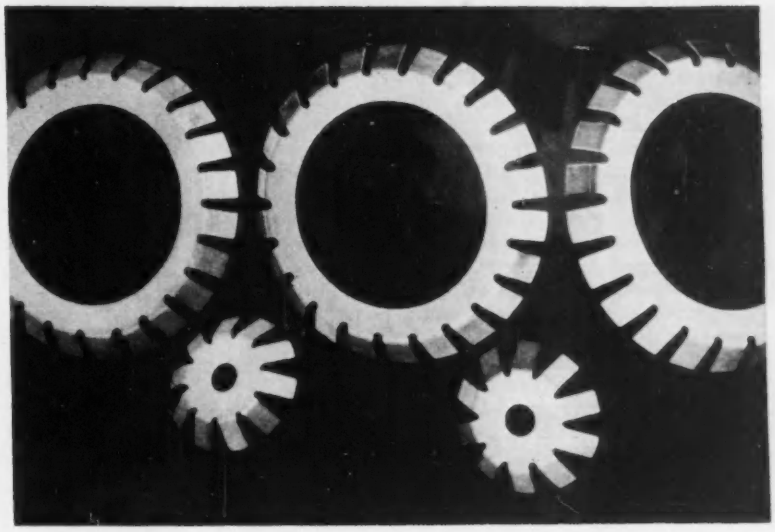
This shell acts as a cushion to protect against impact damage and insulates the porcelain against thermal shock. It will hold operating line pressures against leakage even though the porcelain is cracked or broken.

The armor material is available on the following fittings made by this company: standard Y valves; flush valves; pipe and fittings ½ in. to 8 in.; plug cocks; and safety valves. In addition, the armoring method is said to make it adaptable to special shapes.

Lapp Insulator Co., Inc., Process Equipment Div., LeRoy, N. Y.

CONTINUED ON PAGE 207

Cup Expanders Increase Life of Cylinder Packing



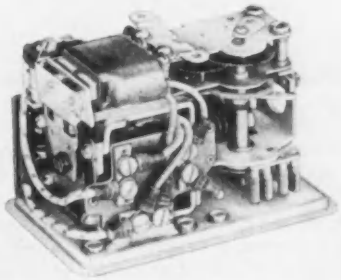
Developed to eliminate leakage in hydraulic and pneumatic cylinders, a new line of cup expanders, designated ES-11, give positive sealing action of cup packings at all times by exerting controlled pressure on the packing lip so that it maintains constant contact with the cylinder wall. This will reduce packing shrinkage, while at the same time increase effective packing life.

These cups may be used on equipment such as pumps, compressors, hydraulic presses, jacks, air cylinders, feed mechanisms, and lubricators. They are available in sizes for use with all standard hydraulic and pneumatic packing diameters from $1\frac{1}{4}$ to $2\frac{7}{8}$ inches.

The series ES-11 cup expanders are fabricated from 0.010 in. thick, rolled strip brass, and are not affected by brine, gasoline and alcohol. In addition, these cup expanders can be quickly installed, eliminating the need for special adapters or design changes on clamping plates or other parts. They will not increase friction or wear on packings because the controlled pressure exerted is only great enough to properly support the packing. The new cup expanders add to the manufacturers line of strip expanders, which is recommended for use with air or hydraulic cylinder diameters greater than 3 inches.

HPL Mfg. Co., 15247 Miles Ave., Cleveland 28, Ohio

Time Delay Relays for Special Application



Shown in the illustration is the model 523-A solenoid wound, spring driven time delay relay for special aircraft applications such as guided missiles and pilotless aircraft. The timer is wound almost instantaneously, 0.025 to 0.10 seconds, varying with coil arrangement and loading. As the control circuit is energized, the switch throws over immediately. The time delay period begins when the control circuit is broken, but the switch remains thrown over until the end of time cycle, when the switch returns to its original position. The unit is then ready for re-cycling when the control circuit is restored.

As a protective feature, in event that the circuit is restored before expiration of time delay period because of natural or planned interference, the unit instantaneously rewinds and restores total time delay period without disturbing the thrown-over position of switch. Regardless of how many times the control circuit is interrupted for lesser durations than the time delay period, the automatic rewinding of the unit when the control circuit is restored makes sure that the full time delay period expires before the switch can be returned to its original position.

Other types of time delay relays available are: for sustained operating impulse, immediate switch throw, immediate time cycle; sustained operating impulse, delayed switch throw, immediate time cycle; momentary operating impulse, immediate switch throw, delayed time cycle. Switches are furnished in SPST, SPDT, or DPDT. Although the accuracy is reduced because of vibration and low temperature, a time tolerance of ± 20 percent is maintained within the temperature range of -76 F to $+131$ F.

M. H. Rhodes, Inc., 20 Bartholomew Ave., Hartford 6, Conn.

CONTINUED ON PAGE 208

Amplifier Reduces Errors of Loaded Test Circuit

The model 105 Meter Master, an accurate power fre
quency amplifier that reduces the
measuring instruments that load a
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The circuit to be tested is conne
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The coils are random wound on n
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The entire assembly is compact,
hardened steel ratchet and pawl, and

The standard model with balance
measures 2⅛ in. wide, by 4 in. long,

Potter & Bra

Pipe Fittir

For acid work, and where corrosi
or contamination should not take pla
valves, piping, and other equipme
of fully-vitrified solid white porcela
are now available with reinforce
plastic armor. This armor is applied
in the form of multiple layers of heavy
fiberglass woven cloth, impregnated
with a modified phenolic resin of high

shock. It will hold operating line pressures against leakage even though the porcelain is cracked or broken.

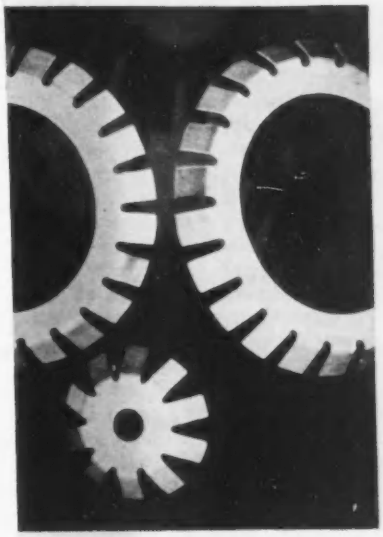
The armor material is available on

make it adaptable to special shapes.

Lapp Insulator Co., Inc.,
Process Equipment Div., LeRoy, N. Y.

CONTINUED ON PAGE 207

Cup Expanders Increase Life of Cylinder Packing



s recommended for use with air or ydraulic cylinder diameters greater han 3 inches.

HPL Mfg. Co., 15247 *Miles Ave.*, *Cleveland* 28, *Ohio*

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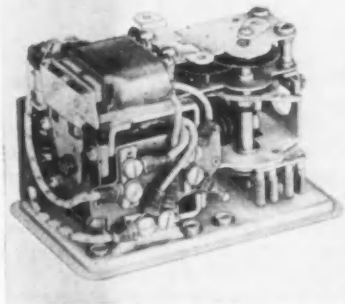


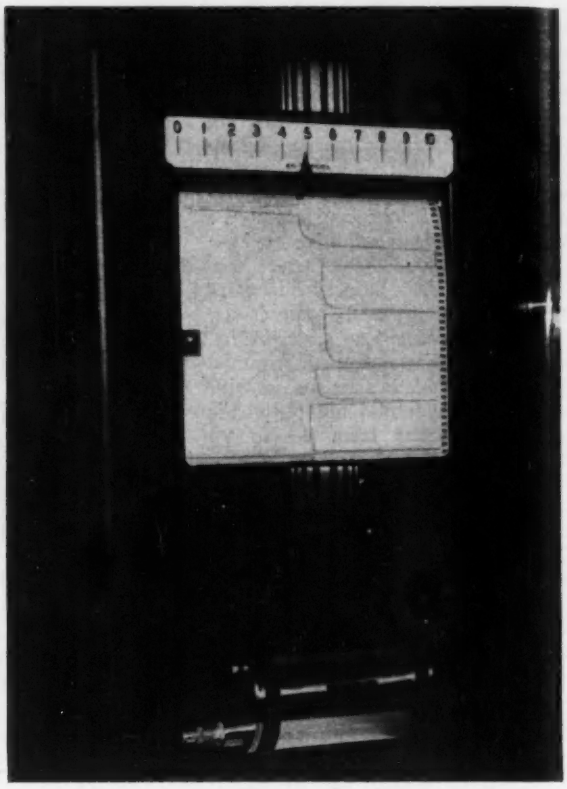
perating impulse, immediate switch hrow, delayed time cycle. Switches re furnished in SPST, SPDT, or PDT. Although the accuracy is re- uced because of vibration and low emperature, a time tolerance of ±20 percent is maintained within the tem- perature range of —76 F to +131 F.

M. H. Rhodes, Inc., 20 *Bartholomew Ave.*, *Hartford* 6, *Conn.*

the thrown-over position of switch. Regardless of how many times the control circuit is interrupted for lesser durations than the time delay period, available are: for sustained operating impulse, immediate switch throw, immediate time cycle; sustained operating impulse, delayed switch throw, immediate time cycle; momentary

CONTINUED ON PAGE 208

Converter Used With High Impedance Recorder



Requiring no high voltage power supply, this small cell, which converts radioactive energy directly into electrical energy, may be used with a high-impedance current recorder. Known as the new model RT cell, it was designed for precision measurement of gamma radiation, but may be used for continuous monitoring of ambient radiation such as is encountered in health physics work, or to follow continuous processes where gamma ray activity is present. The cell is built with a centrally located sample well, permitting use of the cell for the accurate preparation of radioactive dosages for the medical services, as it is possible to get almost 100 percent geometry. When connected to the recorder, a permanent record of production is made which not only shows the number of doses prepared, but also records the amount of activity in each dose. The cell may also be used with a number of standard indicating instruments similar to those used for pH measurement. When used with a recording or an indicating instrument, signal contacts may be included to sound high or low alarms, or pneumatically or electrically operated control mechanisms may be used for the automatic control of processes.

The sensitivity of the Ohmart Model RT cell is such that, when calibrated for measuring samples placed in the well, one tenth full scale reading on the recorder is equal to five microcuries of radium. When calibrated for measuring ambient radiation, one tenth full scale reading is equivalent to two milliroentgen per hour. Accuracy of the cell is not affected by changes in ambient temperature, barometric pressure, or relative humidity, and length of leads between cell and instrument is not a critical value.

The Ohmart Corporation, 2347 Ferguson Rd., Cincinnati 38, Ohio

Heavy Duty, Cam Actuated Micro Switch

A snap-action switch designed for high-precision performance in heavy duty, cam actuated service, has the capacity to make or break steady state currents of 20 amp, and to handle inrush currents as high as 75 amperes.

This new design has a roller plunger actuator adapted to operation by cams with a rise of up to 30 deg, and comes in models with the plunger on the left or right side of the enclosure. The plunger assembly can be turned to any position necessary to align the roller with the direction of the cam approach. A nut is then tightened down to clamp the plunger assembly in this position.

Listed as BAF1-2RQ9-LH and —RH, the units are SPDT switches. Underwriters' Laboratories list these switches: $\frac{3}{4}$ hp, 115 v a-c; $1\frac{1}{2}$ hp, 230 v a-c; 20 amp, 125, 250, or 460 v a-c; 10 amp, 125 v a-c "L"; $\frac{1}{2}$ amp, 125 v d-c; $\frac{1}{4}$ amp, 250 v d-c. ("L" rating denotes suitability for controlling tungsten filament lamp load on alternating current).

Other characteristics are: operating force, $2\frac{1}{2}$ lb, max; release force, $\frac{3}{4}$ lb, min; pretravel, $\frac{3}{32}$ in., max; differential travel, 0.010 in., max; overtravel, 0.187 in., min; weight, approximately 0.55 pound.

Micro Switch, Freeport, Illinois

CONTINUED ON PAGE 210

Steel Lockers Reinforced by Cold-Formed Shapes

A leading manufacturer of steel lockers uses Bethlehem Cold-Formed Shapes as 1 in. x 1 in. reinforcing angles. We form these sturdy 13-gage shapes by cold-rolling, and supply them in lengths from 16 ft to 22 ft.

Reinforcing angles for lockers are only one example of the growing variety of parts and products made from Bethlehem Cold-Formed Shapes. Lately we've formed and, in some instances, fabricated shapes for such diverse uses as door tracks, radiant baseboard sections, storage racks, and hatch covers for sea-going vessels. Manufacturers in widely separated fields regularly come up with ideas for new applications.

Bethlehem Cold-Formed Shapes are regular or irregular shapes formed cold from strip, sheet or plate steel. They are uniform in thickness, with a surface relatively free from scale. They have a high strength-to-weight ratio. We make them on presses, brakes or rolls in all gages from 5 to 24.

Perhaps there's a place where Bethlehem Cold-Formed Shapes could be useful in your business. Why not talk it over with a Bethlehem engineer?

BETHLEHEM STEEL

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

Second Divided into 8 Million Parts

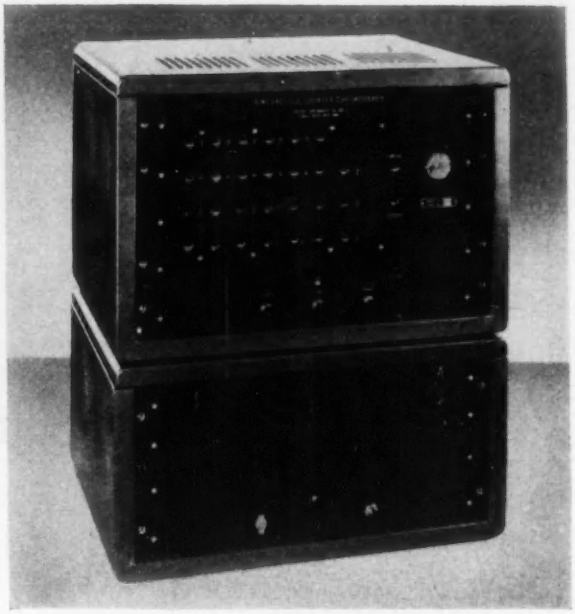
Known as the model 470, the latest counter-chronograph measures elapsed time in steps of 0.000000125 second. This new instrument has an 8 mc crystal oven for a precise time cycle generator, and special gating techniques limit the error to plus or minus one-eighth microsecond.

Results are exhibited on readout lamps in numbers, in whole decimals from a microsecond up, and in fractions down to one-eighth microsecond. For intervals longer than one second, the counter-chronograph will re-cycle and a mechanical register may be used to extend the count.

Start and stop pulses, derived externally from contact closures, or other means, alternately pass and block time base oscillations into a series of counter dividers. These positive pulses defining the interval to be measured may be applied to a common or separate inputs. Lockout circuits prevent interference by subsequent pulses.

When furnished with a high-speed digital-recorder, intermittent automatic reset is provided while the measurements are transferred to electrically sensitive paper.

The model 470 may be used wherever microsecond timing is required: for determining projectile velocity; frequency measurements in telemetering; gas tube and geophysical measurements; timing of camera shutters.



Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.

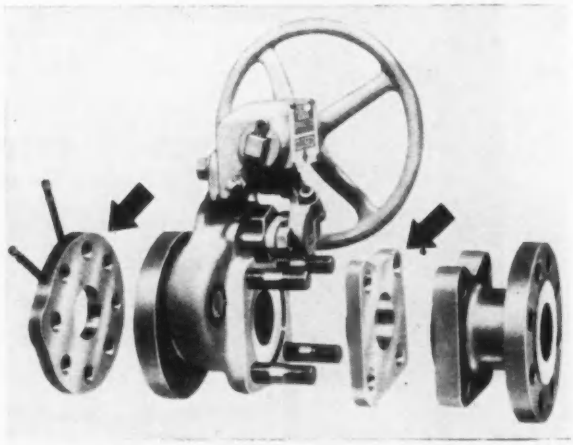
Electrically Heated Valves for Low Temperature Work

An electrically heated valve, believed by the manufacturers to be the first commercially successful unit, was designed to keep valve mechanisms clear of frost and ice in liquid carbon dioxide lines at temperatures as low as —110 F. Other applications are being developed which include both hot, cold, and viscous liquid gas lines, as well as uses where heated valves have been impractical.

Single-disk valves require the heating element shown at right in the illustration. Double-disk valves can be equipped with both elements illustrated. Heat from the elements is transmitted directly to the valve seats, and as a result, heat the entire flow opening through the valve, in addition to the operating mechanism.

All heated valve sizes from 2 to 6 in. are available, with pneumatic, hydraulic, solenoid, or manual control. Heating elements can be provided for either 110 or 220 v operation, with inputs from 400 to 3,000 watts per unit.

Where flanged type valves made by this company are now in service, heating elements may be installed by exchanging standard studs for studs an inch longer.



Okadee Co., 322 S. Michigan Ave., Chicago 4, Ill.

A DETACHABLE V-LINK BELT, that is prestretched, and will not slip, has features that prevent distortion after use, and gives vibration-free operation at top speeds in either direction. The links are said to have more plys than other V-link belts, and are made from tough woven cloth impregnated with top grade heat and oil resistant crude rubber. Brammer Co., 684 Broadway, New York 12, N. Y.

A NEW TYPE OF SUBMINIATURE PAPER CAPACITOR, designed for operation at temperatures through 125 C, are using a new high temperature impregnant. These AQ capacitors are said to have good capacitance stability over the temperature range from —65 to +125 C, without derating, low power factor, and high test voltage. They have good operating characteristics on both a-c and d-c voltages. Astron Corp., 255 Grant Ave., East Newark, N. J.

CONTINUED ON PAGE 212

Don't Let Copper Restrictions Stump You

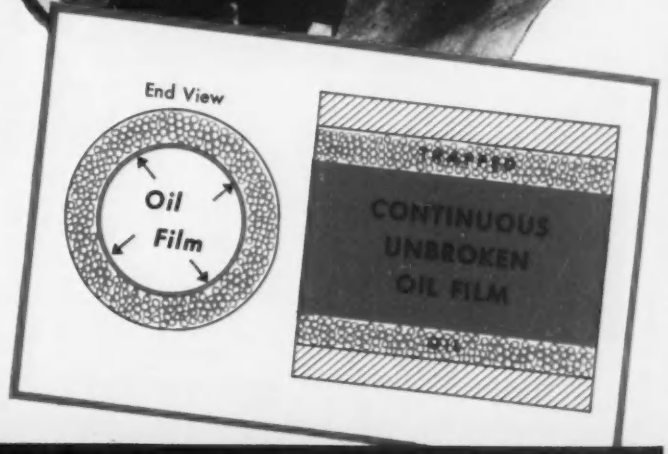
IRON BASE

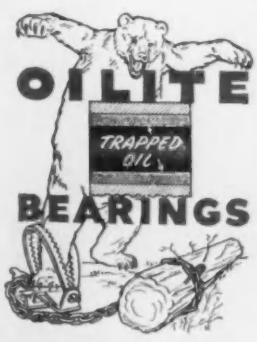
OILITE

GIVES YOU TOP BEARING PERFORMANCE

- Iron Oilite is an excellent heavy duty bearing material.
- It is a sturdy material, and the load carrying capacity is increased by the hydraulic cushion of the trapped oil with which the bearing metal is impregnated.
- Iron Oilite bearings provide the acme in lubrication; a continuous, unbroken, oil film, on the bearing surfaces.
- Iron Oilite is available in all types of bearings and over a broad range of sizes.
- Iron Oilite is only one of the famous Oilite family of products created by Oilite powder metallurgy.

AMPLEX MANUFACTURING COMPANY
Subsidiary of Chrysler Corporation
Detroit 31, Michigan





FIELD ENGINEERS AND DEPOTS THROUGHOUT UNITED STATES AND CANADA

Oilite Products include:
BEARINGS, Finished Machine Parts, Cored and Solid Bars, Permanent Filters and Special Units in both ***NON-FERROUS*** *and* ***FERROUS*** *Metals*

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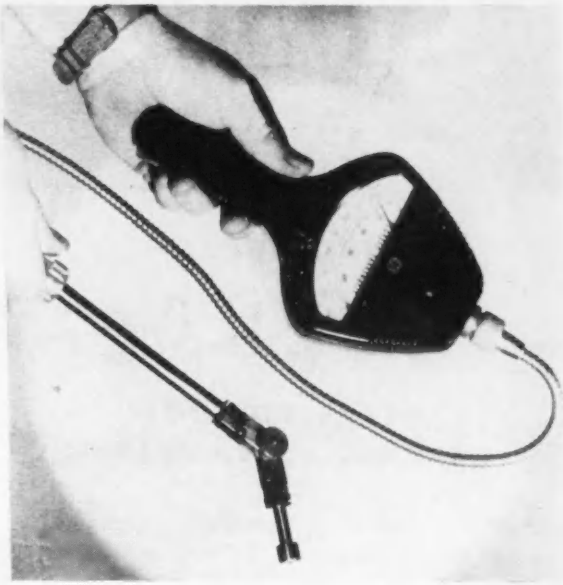
Hand Pyrometer With Two Scale Ranges

A hand pyrometer with two scale ranges for the rapid measurement of surface, liquid, gas and molten-metal temperatures is said to be useful where a temperature detector does not need to be installed permanently. Designated as the type FH-1, the pyrometer's two scale ranges are 0-500 F and 0-1,500 F, and the change from one scale to the other is accomplished by the flick of the switch. The accuracy of the instrument is $\pm 2\frac{1}{2}$ percent of full scale at the instrument cold junction temperature of 80 F. There is automatic cold junction compensation on both scales.

Three interchangeable tips available for the new pyrometer include a surface tip, an immersion tip for liquids and molten metals, and a two-prong contact tip. These tips, together with flexible and rigid extension arms, can be easily changed. The length of the stainless steel rigid arm is 14 in.; the flexible arm, 34 inches.

The automatic cold-junction compensation feature of the FH-1 eliminates any manual adjustment of the pointer for variations in temperature of the instrument or its surrounding atmosphere. Readings can be made directly from either scale of the instrument, since no calculations or corrections are needed.

Typical applications include: temperature checks of plastic molds, ovens, alloys with low melting points, and pre-heated metals for welding, and die and sand casting.



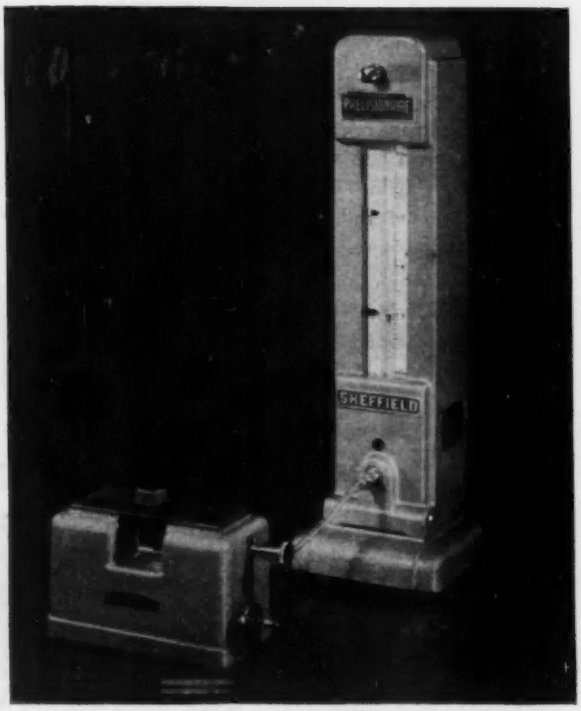
General Electric Co., 1 River Rd., Schenectady 5, N. Y.

Precision Device Checks ID, Taper, Out-of-Round

Solving the problem of accurately checking small rings having internal diameters one inch and under, is accomplished by this device known as the precisionaire internalchek, used in conjunction with a column type precisionaire. In addition to checking internal diameter, the precisionaire internalchek also accurately indicates taper, bellmouth, and out-of-round conditions present in the part. Rings ranging in size from $\frac{5}{32}$ in. to 1 in. internal diameter can be checked on this standard instrument. On special order the instrument may be made to check internal diameters as small as 0.120 inch. They can be explored to a depth of $\frac{9}{16}$ in. from each side by a hand-wheel vertical adjustment of the diamond tipped gaging arms. Gaging pressure is light so that the gaging fingers are not distorted.

The new precisionaire internalchek is said to offer advantages over conventional methods of checking small ring gages. It is a time saver, and a relatively inexperienced operator can easily adjust the ring on the gaging fingers so that the float indicates the true diameter. This does away with the necessity for a highly developed sense of feel as required when using plug gages or inside micrometer. No matrix impressions are necessary.

Other precisionaire instruments, in addition to the radial clearance and race matching gages, may be used for checking the bend and twist of connecting rods, the size and alignment of crankshaft and camshaft bearing bores in cylinder blocks, center distances of holes in transmission parts, squareness, straightness, and other dimensions.



The Sheffield Corp., Dayton 1, Ohio

CONTINUED ON PAGE 214

DIE CASTING cuts costs 66⅔%

CASE HISTORIES FROM MT. VERNON FILES

Seeking to lower manufacturing costs without any sacrifice of product quality, Jaen Electromotive Corporation, of Long Island City, N. Y. gave die casting a chance to solve the problem of producing gear-train housings for synchronous motors. Previously, such housings had been sand cast.

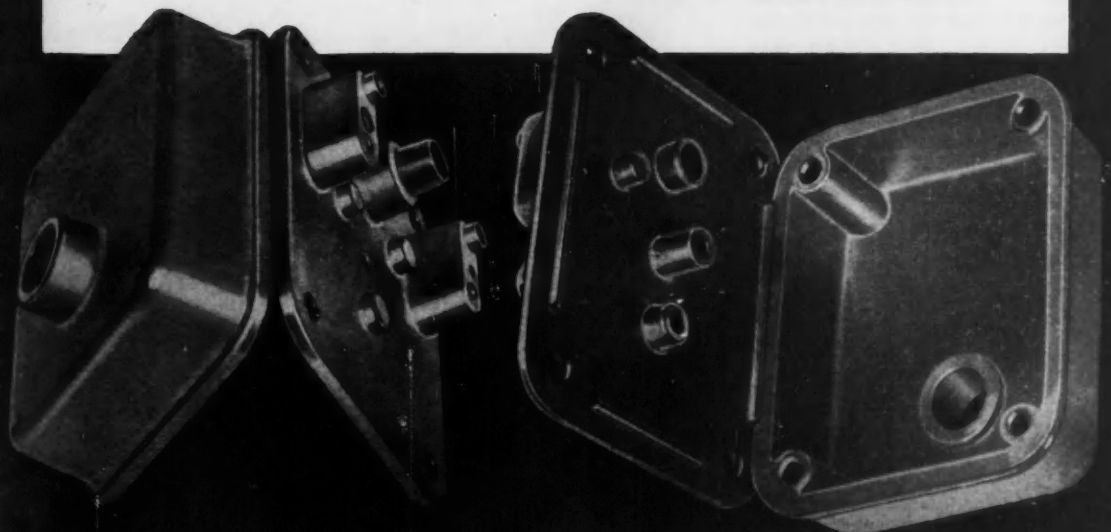
The result of the experiment is that Jaen *now specifies die casting.* For it has found: (1) the "clean" die castings produced by Mount Vernon cut machining costs over 50%; (2) an etched name-plate can be eliminated, since die casting permits company name and motor specifications to be clearly cast into the housing; (3) over-all appearance of the die cast units is decidedly superior.

Added to these advantages, are those realized *on the spot,* as the casting is made. Namely, *extremely fast production,* since die cast items are produced virtually in one operation, as the die closes; and *savings in material.*

Says Jaen Electromotive Corporation: "The over-all cost of the die castings is only *one-third* that of the machined sand cast aluminum pieces initially used. We shall be able to reduce our list price on this type of unit, and increase sales appreciably."

The next time *you* have to select a manufacturing procedure, remember this example of remarkable savings made possible by die casting — and consult with us. We shall welcome the opportunity to help you increase your output, improve your products, and *hold down your production costs.*

MT. VERNON
DIE CASTING CORP.
MT VERNON NEW YORK



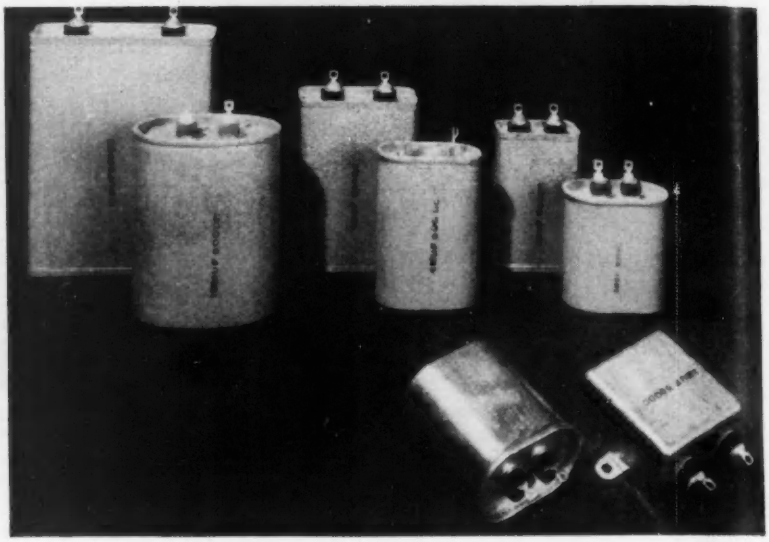
A-c and D-c Capacitors in Drawn Oval Containers

A newly designed line of capacitors for electronic applications has resulted in reductions of 20 to 30 percent in size, and 10 to 20 percent in cost.

Basic construction of the drawn-oval capacitors is essentially the same as that of standard rectangular commercial types of fixed paper dielectric capacitors. The oval capacitors use thin Kraft paper, soft aluminum foil, and pyranol for the liquid dielectric, and less of such critical materials as tin, lead, aluminum, and steel. The new units are said to be mechanically stronger and are less likely to leak because of the drawn-oval construction of the container, which has a single seam, hermetically sealed.

For upright mounting, JAN-C-25 brackets, with the top curve to fit the edge of the capacitor, are used.

The ratings of the new oval capacitors are 2.0 muf to 10.0 muf, 600 to 1,500 v d-c, and 330 to 660 v a-c.



General Electric Co., 1 *River Road, Schenectady* 5, *N. Y.*

New Strong, Thin Gage Insulating Material

A new thin gage insulating material made from glass fiber reinforced polyester is said to be highly resistant to elevated temperatures in electrical apparatus, in addition to having good arc tracking resistance and dimensional stability. It also punches easily with accurate detail.

Known as glastic 940, the material will not flake and separate, and is said to have greater body stiffness than treated fabric type insulation. It is being manufactured according to NEMA thickness tolerance standards, and is available in standard sheet sizes of 24 x 36 inches.

The new 940 material is said to be the only known glass mat reinforced laminate in production available in $\frac{1}{32}$ in. thickness as required for special insulating applications such as relay build-ups, resistance welding transformer barrier insulation, top-stick material in motors, transformers end wrapping, and various television parts. It also may be used in applications requiring dimensional stability and heat resistance, such as in aircraft generators, class B motor insulation, and small electrical unit manufacturing. Apparatus in which this material has been used includes: transformers, motors, relay switches, circuit breakers, generators, vibrators, interrupters, and control devices used in power transmission and control, electrical traction drive equipment, radio, radar and electronics, automotive and aircraft electrical units, and domestic appliances. The manufacturers claim that the glastic material offers a reduction in cost as compared to similar types of insulating material, and is said to be stronger and more stable than fuller board, pressboard, or vulcanized fiber.

The Glastic Corp., 1823 *East* 40 *St., Cleveland* 3, *Ohio*

CONTINUED ON PAGE 216

SHEAFFER'S® *select* PRP "O" RINGS *for precision performance!*

Sheaffer's should know! Who's more concerned about leak-proof product performance than a fountain pen manufacturer?

Sheaffer's put PRP "O" Rings to work in their ingenious new "One-Stroke Touchdown" filling mechanism because they meet every requirement of compact installation, corrosion-free association with Forticel plastic, trouble-free sealing and economy.

Everyone's finding, it's PRP "O" Rings for top quality, long life and economy. They may be the perfect solution to **your** product problems. Find out for yourself. Write today!

Precision Rubber Products CORPORATION

The "O" Ring Specialists

Dept. 3, Oakridge Drive, Dayton 7, Ohio

Pressure Transmitter for Digital Computers

A new pressure transmitter, the Digitran, available for ranges from 0-3 psi absolute to 5,000 psi absolute has been designed for use with digital computers, automatic process control, and digital recording systems. By using the magnetic field vibrating wire principle, this instrument generates a frequency output variable with pressure, or other physical variables. The use of the stable frequency output can be counted for a specified period of time, and a digital number is provided in the electronic counter equal to the pressure experienced. This new technique is said to give increased accuracy, resolution, readability, and recording without the need for additional conversion equipment to digital numbers.

The design is available in models 500, 501, 502. The model 500 is 1 x 1 x 3 in. in size for telemetering applications where temperature control is provided externally. The models 501 and 502 are supplied with temperature control for stable operation under variations of ambient temperature; the size is 3 in. in diameter by 4 inches. The model 502 is supplied with two encased digitran elements. A reference frequency output and frequency output proportional to pressure are both included. These outputs are mixed with available Heterodyne units in order to give direct reading in number form of the physical variable in terms of psi, inches, force and others.

These instruments are said to give advances in the accuracy of measuring physical variable (1 part in 2,000) in telemetering systems, data transmission systems, automatic data recording, automatic control computing systems,

and as a pressure standard for manufacturing operations. Associated equipment such as power supply, amplifiers, and heterodyne units are available for rack mounting on a 3½ x 19 in. panel. Additional information on this device may be obtained from the manufacturer.

Wright Engineering Co., 180 *E. California St., Pasadena, Calif.*

Rotary Actuator For Driving Flexible Shafting

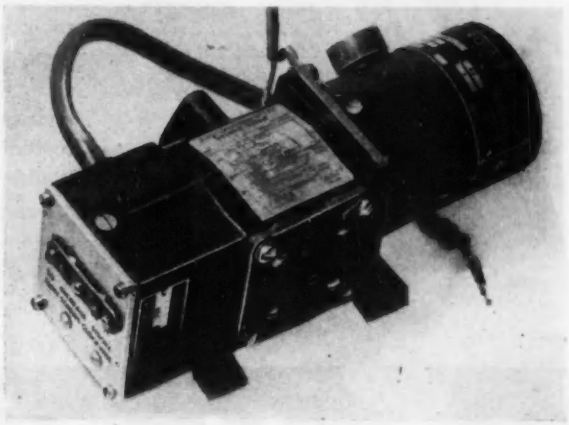
A lightweight rotary actuator for driving flexible shafting in remote operating mechanisms is capable of operating at all altitudes up to 50,000 ft, and through an ambient temperature range of from —65 to +200 F.

The unit was designed for operation on 220 v, 400 cycle, 3 phase a-c. Output is rated at 13 lb-in. at 2,900 rpm of the output shaft. Limit switches control turns of output shaft, and a three phase a-c brake stops the output shaft within 10 turns.

Intermittent operation is 1 minute on, 19 minutes off. Horsepower is rated at 0.6, with the motor fully protected against thermal overloads, internal condensation, dirt and foreign matter.

The unit can also be adapted to 24 v d-c operation. It is approximately 1.25 x 3 x 2.75 in., and is mounted on four drilled pads. Weight is 5 lb, 6 ounces.

Hydro-Aire, Inc., 3000 *Winona Ave., Burbank, Calif.*



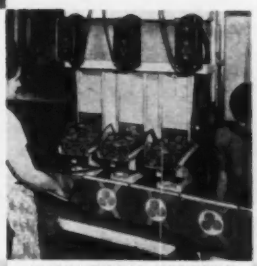
A FLEXIBLE COUPLING that withstands pressures in excess of 375 psi and temperatures from —65 to 460 F on fuel and oil lines may be misaligned as much as three degrees without leaking, and tube ends may be separated as much as one half inch without affecting sealing. End load is absorbed with a metallic retainer, preventing stress on the sealing members. Standard AF 934 O-rings are used. The coupling is light-weight, and can be installed after tubes are in place without making large cutouts. While present uses are on connecting fuel tanks and refueling lines, the manufacturers believe that the coupling may be used wherever vibration and flexure creates a connection problem. E. B. Wiggins Oil Tool Co., Inc., 3424 East Olympic Blvd., Los Angeles 23, Calif.

CONTINUED ON PAGE 218

What's Your Problem?

Clogged bins and hoppers? Slow, unreliable, uncontrolled material feed? Lack of sizing or separation? Does the product require settling or packing down in containers? Are you fumbling around with small parts? Inefficient industrial heating methods that are costly to operate and maintain? Difficulties with current conversion? Leaky shafts? Slow, laborious hand batching?

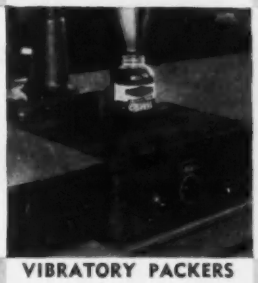
BIN VIBRATORS



VIBRATORY FEEDERS

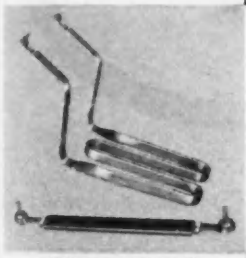
VIBRATING GRIZZLIES

VIBRATING SCREENS

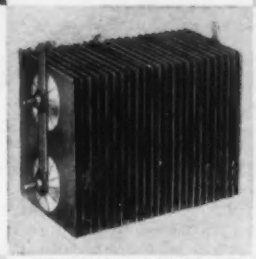


VIBRATORY PACKERS

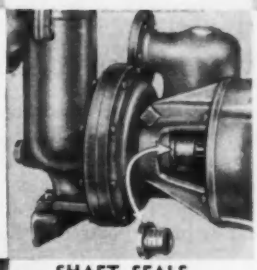
PARTS FEEDERS



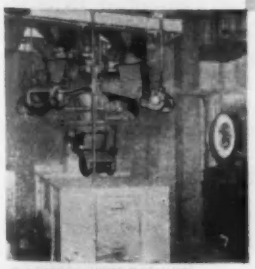
ELECTRIC HEATING ELEMENTS



SELENIUM RECTIFIERS



SHAFT SEALS



BATCH WEIGHING

Then ask about—

SYNTRON

ELECTRIC VIBRATORS, promoting free-flowing bins, hoppers and chutes.

VIBRATORY FEEDERS, controlling the flow of materials in packaging machines, etc.

VIBRATORY PACKERS, settling materials in containers and molds.

PARTS FEEDERS, feeding small objects to automatic machinery, machine tools, etc.

VIBRATING GRIZZLIES, for rough scalping.

VIBRATING SCREENS, removing foreign objects, lumps, etc.

SHAFT SEALS to eliminate leakage of gases and liquids.

BATCH WEIGH SYSTEMS, with scale-controlled Feeders and Vibrators.

ELECTRIC HEATING ELEMENTS, thin, flat, sheathed with extremely uniform heat distribution.

SELENIUM RECTIFIERS for efficient conversion of AC to DC.

SYNTRON CO.

890 Lexington, Homer City, Pa.

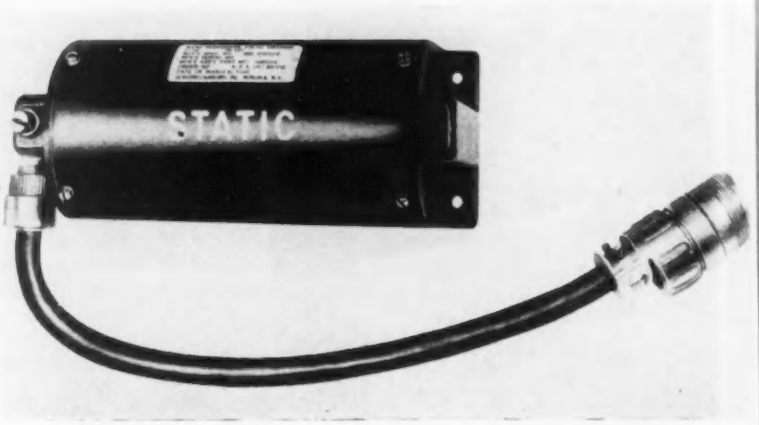
Transducers for Precision Instrumentation

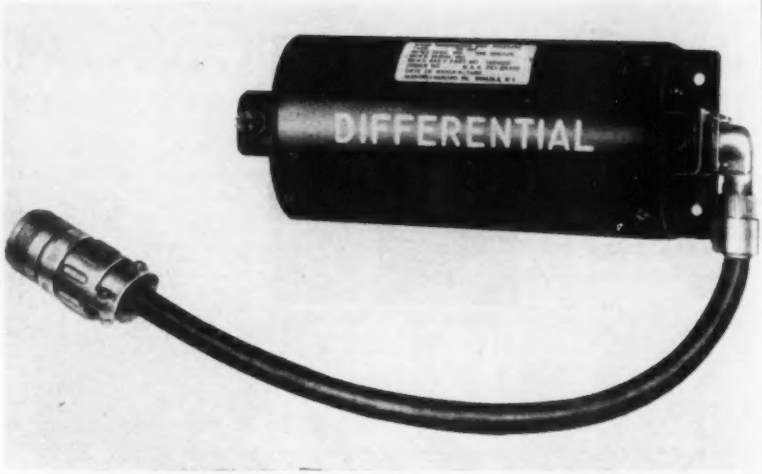
Two new transducers, the static pressure (TR 101), and the differential pressure (TR 102) are precision built, 400 cycle instruments which convert static and differential air pressures, respectively, into electrical signals for use in conjunction with precision instrumentation, and analog computers. These instruments are suitable for commercial and military applications, and particularly for use in electronic and electromechanical instrumentation common to airborne equipment.

The manufacturers claim that the new design has such features as: absence of bearing and sliding contacts to eliminate frictional errors, reduce hysteresis, and increase repeatability; bourdon tube construction of zero thermoelastic coefficient material to reduce temperature sensitivity; thermostatically controlled heaters for reliability over wide temperature ranges.

The transducer is of the electromagnetic type made of a variable reluctance magnetic pick-off bridge circuit, and a cantilever suspended bourdon tube of special design. It accepts gas pressure as its input and depends for its operation on a change in the reluctance of the magnetic circuit, eliminating any mechanical friction.

The measurements of both units are 2½ x 2½ x 7¼ inches. Weight of the TR 101 is 2 lb. 4 oz; and the TR 102 2 lb. 6 ounces. The output voltage range of the TR 101 is zero to 2.94 v, with 26 v excitation. The output voltage range of the TR 102 is zero to 3.05 v with 30 v excitation.





Servomechanisms Inc., Post and Stewart Ave., Westbury, L. I., New York

Wide Control With Fluid Powered Speed Reducer

A recently developed fluid powered speed reducer makes available all the gear ratios of conventional speed reducers, with complete control of motor speed from 0 to 2,000 rpm at constant torque, and with full reversibility. In addition, extreme torque down to 1 rev per min. is possible.

Because fluid motors are essentially constant torque devices when supplied with oil at a constant pressure, the torque output of the combined fluid motor and speed reducer or increaser is almost constant throughout the entire speed range. The torque may be changed by the pressure of the hydraulic oil supplied to the fluid motor. By reversing the flow of oil to the fluid motor, the rotation of the output shaft can be reversed.

As the hydraulic system is designed to operate as a closed system at pressures from a few hundred to 5,000 psi, it is waterproof, and can be used in damp locations where electrical power is hazardous. For the same reason, it can be used in locations where fireproof or explosionproof electrical equipment is not adaptable. Because of the many combinations of gearing arrangements and fluid motors, a wide range of speed can be obtained to meet the different requirements.

Fluid motors are available from fractional hp sizes to 250 hp. As an example of size, a unit having an output of 5 hp and a maximum speed output of 25 rpm, would have a width of 16 in., and a height of 18 inches.

Oil to drive the fluid motor would be supplied from a hydraulic power unit consisting of a motor driven pump. The control of the speed and torque of the fluid motor is obtained by control valves, or controls built into the pump or pumping unit.

The Rucker Co., 4228 Hollis St., Oakland 8, Calif.

CONTINUED ON PAGE 220

another case where welded steel tubing does the job best . . .

ELECTRUNITE TUBING

helps make grease guns better...

It can help your product, too

It's been years since a motorist had to squirt oil into the oil cups around his car before starting out for a spin.

Today every service station has a variety of powerful pressure grease guns that provide a longer-lasting, squeak-free lube job.

Most likely those guns are made from Republic ELECTRUNITE Welded Steel Tubing . . . light in weight . . . strong to stand rough service. Uniformity of dimension reduces costly machining, smoothness of ID reduces piston wear, helps hold high pressures. Uniformly good OD surfaces take and hold plated finishes, reduce rejection of plated parts after costly finishing has been done.

Service station operators prefer the long, trouble-free service that they get from gun barrels made of ELECTRUNITE Steel Tubing.

We like to tell manufacturers of all types of equipment how ELECTRUNITE Steel Tubing can help them make better products that cost less. May we tell you?

REPUBLIC STEEL CORPORATION
STEEL AND TUBES DIVISION
224 EAST 131st STREET • CLEVELAND 8, OHIO

Made by the producers of ELECTRUNITE The "*Original*" ELECTRIC-WELDED BOILER TUBE

1902 50th ANNIVERSARY 1952 STEEL AND TUBES DIVISION ELECTRUNITE TUBING

Republic REPUBLIC STEEL

ELECTRUNITE TUBING

Alternator Cooled by Water Vaporization

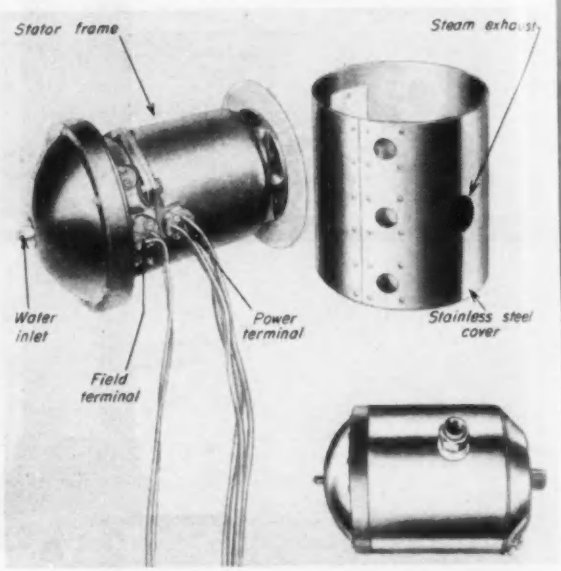
The G-75 alternator, said to be the first successful vaporization-cooled environment-free alternator, will maintain satisfactory cooling while operating in extreme conditions of temperature and altitude. The unit was developed for a guided missile project, as air-blast and fan methods of cooling have limitations at high speeds and altitudes.

The alternator, which is 93 percent efficient, requires 3½ lb of water an hour at rated load, but its operation is limited to a cycle which depends on the capacity of the coolant reservoir. The size of the reservoir is limited by weight and space available in the aircraft.

In operation, coolant from the reservoir is injected into the alternator's hollow shaft under pressure. Centrifugal force sends the water through four ports in spray form, and covers the internal surfaces of the machine. As it picks up heat from these surfaces, the water vaporizes to become the coolant. Resultant steam is exhausted through a port. Water inlet flow is regulated automatically by a valve which is controlled by a temperature-sensing element in the alternator. The three-phase, 400 cycle, 12,000 rpm unit is rated at 12 KVA but can deliver 16 KVA and main satisfactory cooling.

The alternator has a power factor of 80 percent, weighs 39 lb, is 12⅜ in. long, and 9 in. in diameter. The high heats of vaporization keep the weight of the coolant required at 3.4 lb/hr/kw of losses. The heat transfer coefficients for boiling water are 20 to 200 times that for air.

The G-75 has no moving parts, gives good response time, and may be adapted for either blast or vaporization cooling. Low freezing-point coolants may also be used.



Jack & Heintz, Inc., 17600 *Broadway, Cleveland* 1, *Ohio*

Pocket Sized Sound Survey Meter

A new, pocket sized sound-survey meter is said to be much easier to use, and is much lower in cost than standard sound-level meters. The meter has a wide range of applications in fields of sound measurement, and can be used for determining the noise level of machinery, preliminary surveys of noise levels, and simple acoustic measurements.

The instrument consists of a microphone, a calibrated potentiometer, a four-stage amplifier with weighting networks, and an indicating meter. A voltage proportional to the current in the meter circuit is returned to the grid of the second stage as negative feedback, which maintains the gain of the amplifier reasonably independent of normal changes in battery voltage, and aging of tubes. This stabilization makes it practical to eliminate the usual front panel gain adjustments.

The calibrated potentiometer is a continuous level control that permits the person operating the instrument to adjust the level control so that the fluctuating reading of the meter balances about the zero-decibel mark on the meter. Then the level is given directly by the setting of the attenuating potentiometer, which covers the most often used range of from 50 to 100 decibels. An additional 30 decibel attenuation is provided which, with the −10 to +6 decibel range of the meter makes the total sound pressure level range of the instrument from 40 to 136 decibels.

General Radio Co., 275 *Massachusetts Ave.*, *Cambridge* 39, *Mass.*

CONTINUED ON PAGE 222

Your best buy in compact POWER

a hydraulic PUMP or a hydraulic MOTOR

Ready for either PUMP or MOTOR use without alterations

Denison's new simplified vane-type power units offer *interchangeable* pump and fluid motor utility in the most compact design ever offered for hard, continuous duty at 2000 psi. The Pump/Motor shown above — only 8½" long — is available in models that pump from 2.7 to 7.5 gpm at 2000 psi.

Three other sizes offer a choice of models with pumping capacities up to 70 gpm at 2000 psi.

As motors, the four sizes offer high torque ratings from 13 to 257 pound-inches per 100 psi.

Check the added features of these versatile Denison Pump/Motors — then write for full information.

Hydraulically Balanced Vanes. Rugged specially designed vanes contact the cam ring with dual sealing edges. Complete hydraulic balance assures minimum wear on both vanes and cam ring.

No Pulsation. Smooth, hydraulically balanced action brings uniform delivery that reduces surge and pulsation to a minimum.

Interchangeable cam rings for each Pump/Motor size widens the range of capacities for both pump and motor applications.

Convertible. Full radial balance makes each Pump/Motor adaptable to either pump or fluid motor needs *without alterations of any kind* — for continuous duty at 2000 psi.

Bi-directional Rotation. All Pump/Motor sizes and models are readily adjustable for either clockwise or counterclockwise operation.

"A SIZE FOR EVERY NEED"

Four Sizes—plus interchangeable cam rings in each size — provides pumps of sixteen different displacement ratings — or motors of eleven different torque capacities. Write today for full details on Denison Pump/Motors — your biggest buy in versatile, compact power!

The **DENISON** Engineering Co.,
1157 Dublin Road, Columbus 16, Ohio

DENISON Hydr OILics

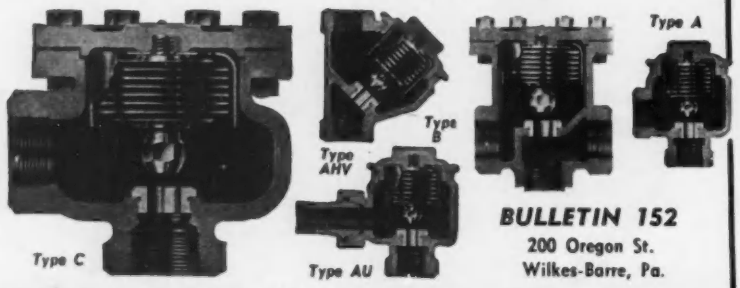
PUMP/MOTOR

"The Finest Money Can Buy!"

Nicholson Traps Help

CUT STEAM COST $500,000 A YEAR

At one of the nation's large processing plants a campaign to promote economical steam use by improving heat transfer efficiency has resulted in a yearly saving of $500,000. Credit for a fair portion of this is given to improved steam trapping which resulted from the installation of Nicholson thermostatic traps. To see why an increasing number of leading plants are standardizing on Nicholsons for positive drainage and faster heat transfer, send for Bulletin 152.



BULLETIN 152
200 Oregon St.
Wilkes-Barre, Pa.

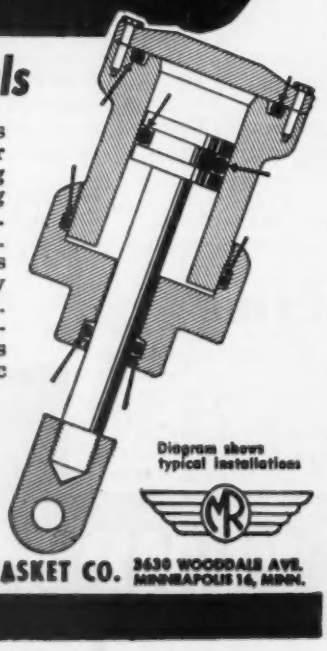
W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

O-RINGS by INJECTION MOLDING

Dependable Hydraulic Seals

Minnesota O-Rings function in air or gas systems as well as in hydraulic systems. Air cylinders . . . hydraulic valves . . . hoisting mechanisms . . . water pumps . . . bottling machines . . . refrigerators . . . motors . . . lubricators . . . are a few of their uses. Minnesota's exclusive injection process makes possible very close dimensions, uniformity in mass production and downright economy. We use special compounds of synthetic rubber to meet your exact requirements. Let us make a quotation on your next hydraulic packing installation.



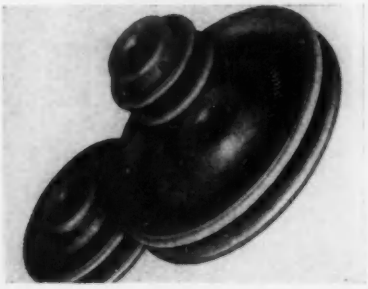
Manufacturers of all types of small rubber parts

Write for O-Ring Catalog

MINNESOTA RUBBER & GASKET CO. 3630 WOODDALE AVE. MINNEAPOLIS 16, MINN.

Molded V-Belt Sheaves For Light Machinery

A line of V-belt molded sheaves for light machinery drives are molded from compolene, a new type of fibrous material which is molded to close tolerances under high pressure. It has a hard wearing surface that is unaffected by moisture, oil, and temperature, and cannot rust or corrode. Compolene is



similar to the material used in pressure-molded gears in the automotive industry in motors, gear trains, and timing gears used under severe wearing conditions. Molded gears and pulleys are said to wear better, weigh less, and run quieter than metal pulleys. The material is not restricted.

The sheaves come in sizes from 2 to 6 in. OD, inn gradations of $\frac{1}{2}$ inch. Bore sizes are $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in., with or without keyways. Total width is $1\frac{7}{16}$ inch.

W. C. Products, Inc., 1748 *Berkeley St., Santa Monica, Calif.*

Short Interval Electronic Timer

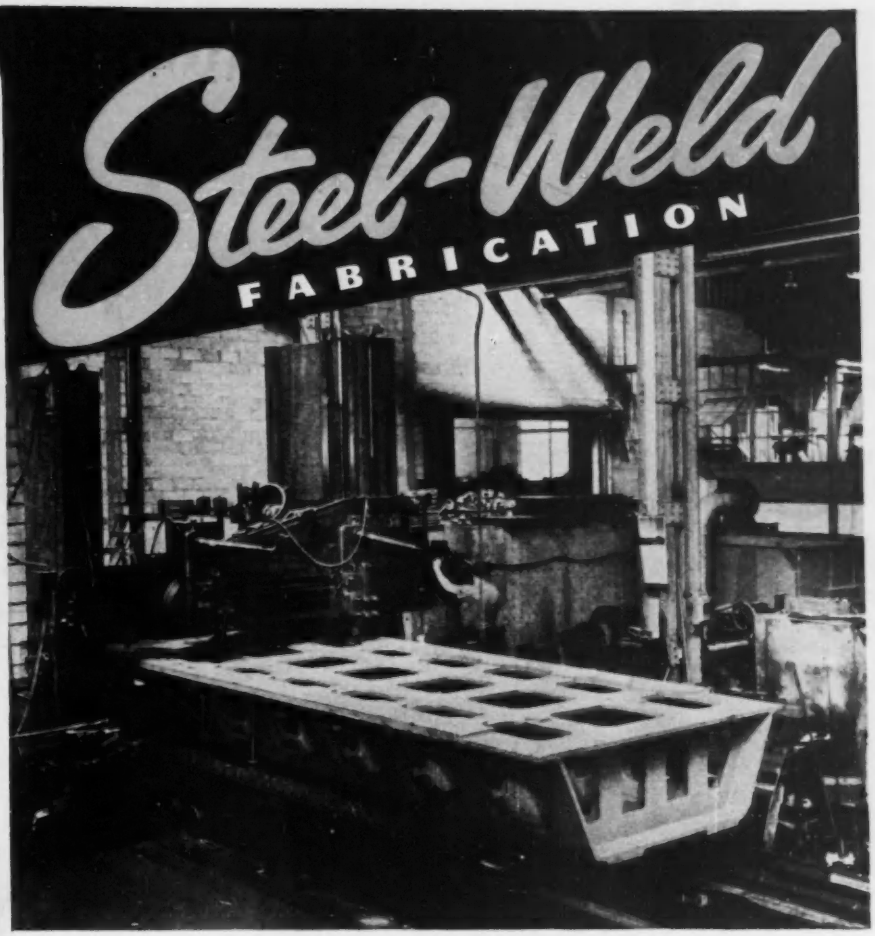
A new promatic electronic timer is capable of controlling timed operations between 60 milliseconds and 60 seconds.

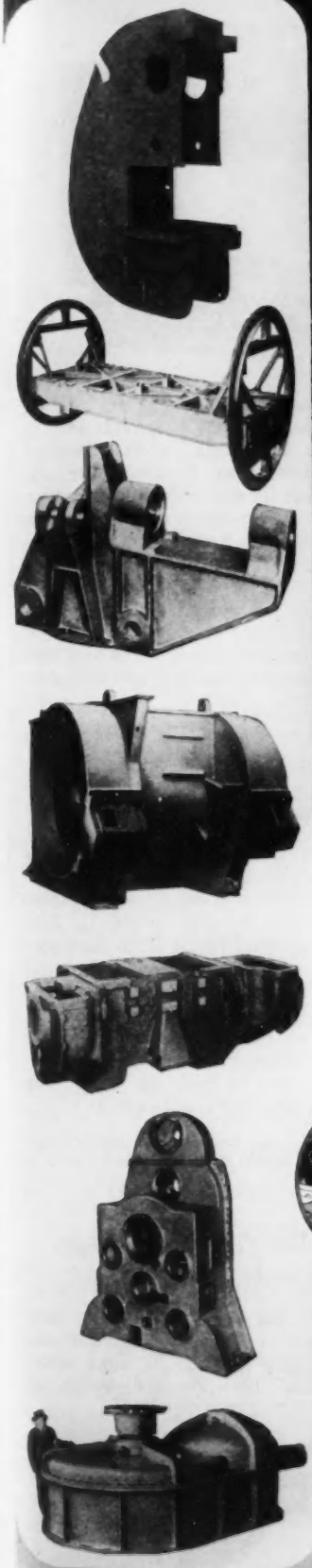
The discharge of a resistor-capacitor network through a sensitive gas tetrode relay tube provides the basis for each timing period, the duration of which may be manually set by a potentiometer. Steps within the overall timing range are covered by plug-in condensers.

The time period is set manually by means of the indicator and the $3\frac{3}{8}$ in. dial. Timing begins when any external switch is closed; control contacts either open or close at end of timing, depending upon actual circuit requirements. Control contacts are double pole double throw, rated at 10 amp, 125 v a-c, non-inductive. Operation is from 115 v a-c or 220 v a-c, 60 cycle.

Similar in appearance to the syn-

Steel-Weld FABRICATION





The twenty-ton weldment above is one of many heavy fixture parts produced by Mahon for the defense production program. It, and the Steel-Weld Fabricated parts and assemblies illustrated at the left, are typical of thousands of units Steel-Weld fabricated and machined by the Mahon Company for manufacturers throughout the country. Do you have parts or assemblies in your product that could be redesigned for more economical production in welded steel? . . . do you have products in the development stage in which Steel-Weld fabricated parts could reduce weight without sacrificing strength? . . . are you faced with limited production on an item involving heavy pieces in which pattern costs are a consideration? If so, it will pay you to familiarize yourself with Mahon facilities and technical services . . . you will find in the Mahon organization a unique source with complete, modern fabricating, machining and handling equipment to cope with any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job, embodying every advantage of Steel-Weld Fabrication.

Use WELDED STEEL for Greater Strength with Less Weight!

THE R. C. MAHON COMPANY
DETROIT 34, MICHIGAN

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON

- **Custom Engineered and Tested**
- **Using all known Spring Metals**
- **Hot or Cold Wound**

Be sure you select the right spring for the job by having your spring requirements thoroughly engineered.

Let us help you with your spring specifications. Our experience over many years in the manufacture of all types of springs for every conceivable application is available to you without obligation.

Fill out the coupon below for "custom engineering" of your spring requirements.

AMERICAN-FORT PITT SPRING DIVISION
H. K. PORTER COMPANY, INC.
2 John Street, McKees Rocks, Pa. *(Pittsburgh District)*

American-Fort Pitt Spring Division
H. K. Porter Company, Inc.,
2 John Street, McKees Rocks, Pa.
Gentlemen:
Have a sales engineer call on me to discuss custom engineering our spring requirements.

Name of Company_____ Date_____
Address_____ City_____ State_____
Name_____ Title_____

chronous-motor timer for timing periods between ½ second and 24 hours, also made by this company, "matched timer housings" are now available for use in dual-timer applications. These timers may be mounted back-of-panel, against a wall, or in the rear of a cabinet. Wide-spaced barrier strips may be located either on the front or the back of the timers.

Typical applications include: automatic process control, on machine tools and molding machines, and laboratory life tests.

General Control Co., Boston 34, Mass.

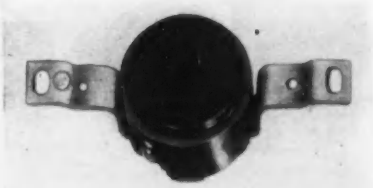
Vibration Isolator Mounts

New shock unit mounts covering the following load ranges: 10-22 lb, 18-40 lb, 25-50 lb, 32-64 lb, 40-80 lb, 55-110 lb, and 75-150 lb, have been approved by the U. S. Air Force. These units have added damping, shock control, temperature range, and strength. Lighter load ranges are made of aluminum, with the higher load ranges made of corrosion resistant steel to meet the 30 g drop test in AN-E-19 specifications.

Federal Shock Mount Corp., 885 Morris Ave., New York 56, N. Y.

T-Polarity, High Voltage Receptacle

A 20 amp, 2 wire, T-polarity flush receptacle is molded of bakelite, and is especially designed for heavy industrial use. It will accommodate all



School Daze!

Just because that bathing suit is proper at the beach, she shouldn't assume it's proper for the classroom, too!

And just because one bearing is best lubricated by one particular grade of oil, you shouldn't assume that the same oil is best for *all* bearings on that machine. In many cases it isn't.

OIL CUPS permit you to lubricate each bearing with the oil best suited to that bearing—thus prolonging bearing life, reducing maintenance costs, cutting down-time, boosting production. And oil cups fortunately *cost very little.*

Gits oil cups have been the standard for industry for more than 40 years. Gits Bros. has the largest selection of oil cups available anywhere. Call on Gits Bros. for a prompt, efficient solution to your lubrication problems.

Write for free Catalog No. 60-A

GITS BROS. MFG. CO.

1838 S. Kilbourn Ave. • Chicago 23, Illinois

WHY NOT cast a magnesium mousetrap?

Maybe it IS a lousy idea . . .

On the other hand, maybe it's as practical as using cheese for bait.

Frankly, we haven't gotten out a slide rule or put our thinking cap on tight, to figure it out one way or the other. Maybe the mice wouldn't go for it.

But we do know a lot of things WILL be cast in magnesium or aluminum after military requirements are satisfied.

A lot of things no one ever thought would be.

So whatever your plans are; whatever directions they might take; whatever products you might have on scraps of paper, in preliminary drawings, or just plain ideas-on-the-brain . . . . keep an open mind in terms of magnesium or aluminum in sand-cast, semi-permanent or permanent mold form.

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Almost a half-century of Experience

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Dept. 16 12800 Shaker Blvd., Cleveland 20, Ohio

standard single outlet plates, yet prevent the frequent blown fuses and other mishaps that occur when a regular parallel-blade cap is mistakenly inserted into a receptacle of higher amperage. It is rated at 20 amp, 250 v, and is Underwriters' listed.

Rodale Mfg. Co., Inc., Emmaus, Pa.

Remote Control Switch

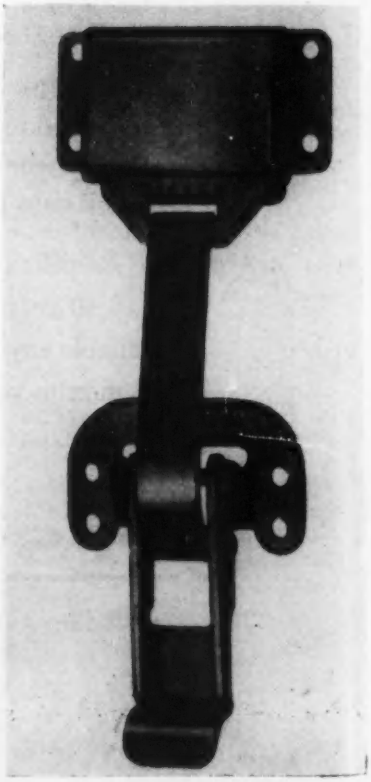
The model SW-T-1 thermal switch for remote on-off control of auxiliary electrical circuits is said to eliminate special wiring and switching equipment.

The switch has small, compact size; easy installation; rugged construction; fast self re-cycling; pure silver-to-silver contact; and mechanical stability. The maximum load of the SW-T-1 is 50 watts; actuating load minimum is 100 watts at 117v; actuating load maximum is 500 watts at 117 volts. Accelerated life tests show 5 years of operation without failure.

The La Pointe Plascomold Corp., Windsor Locks, Conn.

Vibration-Resistant Latch

A new clamp and latch fastener, designed to withstand the most severe vibration and rough handling, and to minimize the tendency of the clamp



Maybe you're missing a bet on

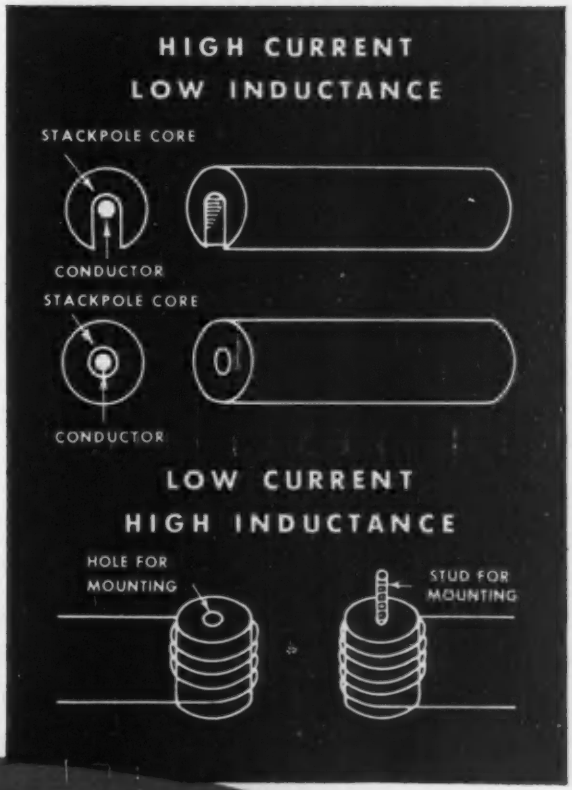
HASH and INTERFERENCE SUPPRESSION!

Recent experience indicates that Stackpole molded iron cores and Ceramag® cores (ferrites) help materially in minimizing "hash" and r-f interference when used in the filter systems of electrical tools and equipment. Their advantages include

- ***Less IR Drop*** **because of lower d-c resistance**
- ***Greater R-F Attenuation*** **because of less distributed capacitance**
- ***Concentrated Field*** **with consequent reduction in coupling to other coils**
- ***Reduced Space Requirements***
- ***Increased Inductance*** **for a given amount of wire . . . . or, conversely . . . .**
- ***Less Wire*** **for the same Inductance**

As one of the earliest pioneers in core production, and backed with a complete line of materials, sizes, shapes and production facilities, Stackpole welcomes the opportunity to cooperate in adapting suitable cores to particular noise suppression problems.

Your inquiry entails no obligation and will receive prompt, skilled attention. Write to Electronic Components Division, Stackpole Carbon Company, St. Marys, Pa.



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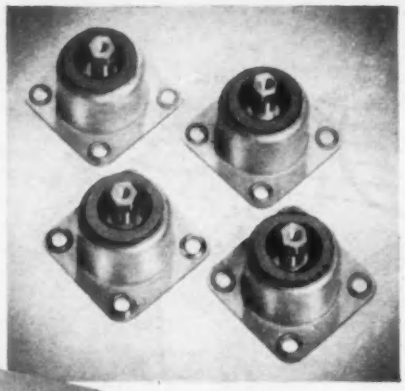
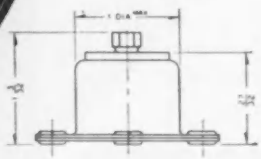


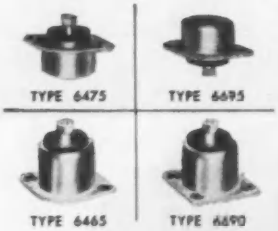
Photo courtesy Vapor Heating Corp.



insures the reliability of your equipment.

Miniature air-damped Barrymounts were developed specifically to help you with your miniaturization projects. They give you these advantages:

1. Less space — reduced height cuts cubage of mounted equipment.
2. Less weight — only 5/16 ounce per unit isolator.
3. Wide load range — 0.1 to 3.0 pounds per isolator.
4. Satisfy temperature (−67 to +170F), vibration, and other performance requirements of JAN-C-172A — special models available for extreme high or low temperatures.
5. Ruggedized models — available for equipment that must meet shock-test requirements of AN-E-19, MIL-E-5272, and MIL-T-5422.
6. Four styles — available as unit isolators or assembled with mounting bases built to your needs.



For complete information, ask for Barry Catalog 523-A; it's free on request. And for greatest benefits with miniature Barrymounts, let our Field Engineering Service share our experience with you in the early stages of your designs.

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opening on impact, has been recently added to a line of specialty clamp and latch fasteners.

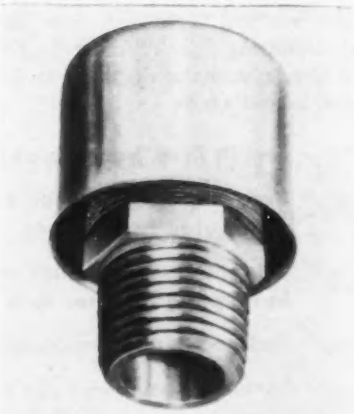
The striker has four coil springs compactly arranged in the top section of the unit, and gives as much as a 100 lb pull on the latch lever, yet permits easy opening and closing by hand.

This special latch is ideal for use in sub-zero temperatures and is not a "knuckle breaker".

The Bassick Co., Bridgeport 2, Conn.

Ribbon Element Air Vent Filters

One of the major performance characteristics of a new series of ribbon element air vent filters is the fact that the new filters give positive controlled filtration. The specially designed element is said to have an



efficiency of approximately 40 micron filtration (0.0016 inches). The unit never wears out and is easily cleaned.

Applications include: hydraulic systems, air compressor intake, carburetor intake for small gasoline engines, crankcase ventilation, fuel tank breather, pneumatic cylinders, and others.

The ribbon element filters are available in ¼, ½, and ¾ in. pipe thread sizes.

Bendix Aviation Corp., Skinner Purifiers Div., 1503 Trombly Ave., Detroit 11, Mich.

Rubber Compound Restrains Shrinkage and Swelling

A recently developed rubber compound called X-1692 is said to restrain shrinkage and swelling, two problems in oil resistant applications. This compound, a Buna N compound of 70 Shore A durometer, has a minimum

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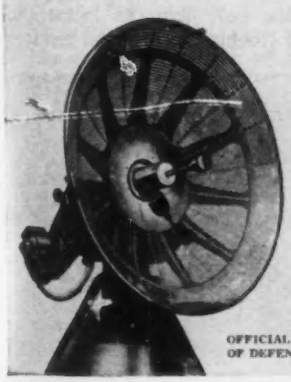

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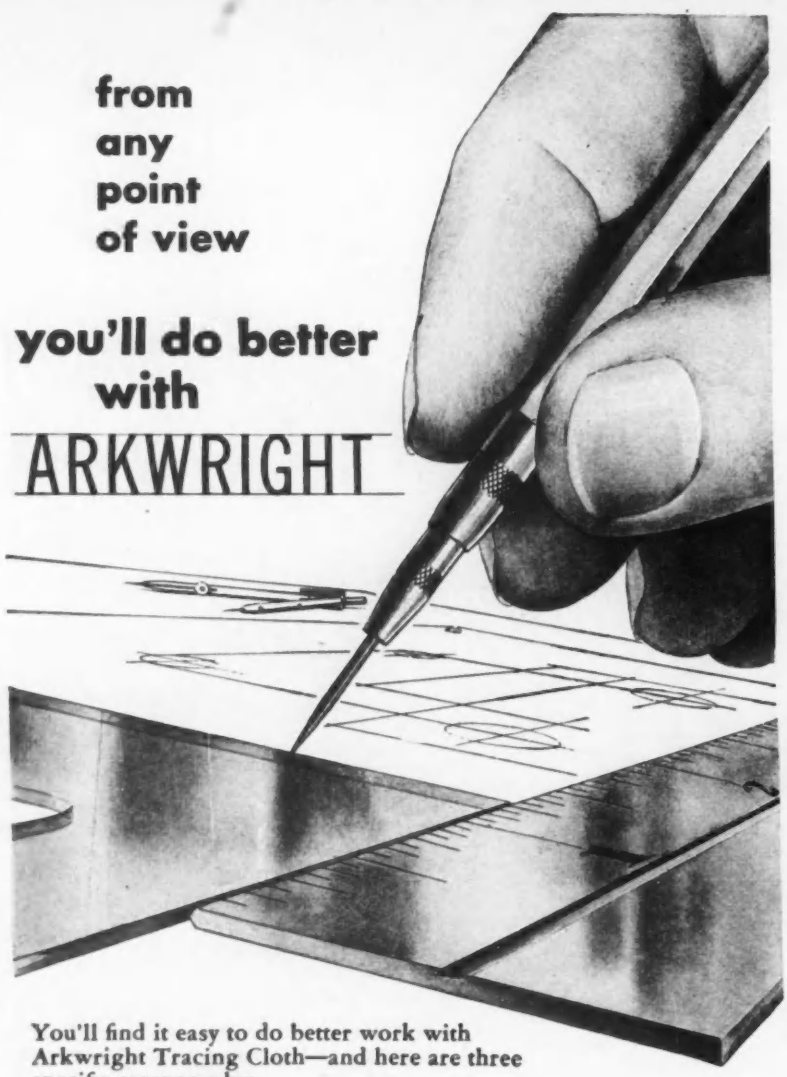

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ARKWRIGHT

Tracing Cloths

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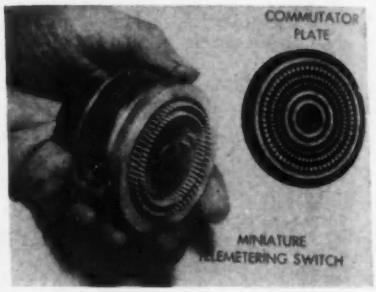
swell in low aniline point oil, and a minimum shrinkage in high aniline point oil. It will not corrode, or otherwise damage such metals as aluminum, magnesium and other alloys, or stainless steel.

The compound is now being used in the production of packings, bushings, seals, and couplings.

Acushnet Process Co., New Bedford, Mass.

Miniature High Speed Telemetering Switch

A telemetering commutator plate, having 180 contacts, and 3 slip rings of coin silver integrally molded, has recently logged over 1,000 hours of maintenance free, high-speed telemetering commutator performance.

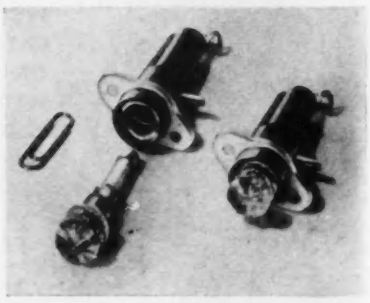


Made of mycalex 410, injection-molded glass-bonded mica, the plate has 30 synchronizing pulses, and samples 60 channels of information such as air speed, altitude, angle-of-attack, temperature, pressure, voltage and other variables.

Mycalex Corp. of America, 30 Rockefeller Plaza, New York 20, N. Y.

Miniaturized Indicating Fuseholders

Latest in a series of compact, panel-mounting fuseholders, a new 440-5FH neon indicating fuseholder takes a standard 3AG or 3AB fuse, and lights up when the fuse blows. Easily installed, the unit helps to locate the source of trouble quickly, and reduces



fuse replacement time to a minimum. Actual replacement is accomplished by a twist of the wrist.

Because of its standard design and construction, it has almost universal application in 110v circuits. With slight modifications it can be used for 220 volts. It mounts on 1 inch centers and takes only 1⅞ in. behind the panel. Large tabs allow for quick connections, and fast soldering.

Alden Products Co., 117 *No. Main St., Brockton, Mass.*

Strong, Thin Disk Ceramic Capacitor

The J-cap, a thin disk ceramic capacitor, has good physical strength while having dimensions of only 0.156 in. maximum thickness, and 0.594 in. maximum diameter. The combination of the completely fabricated high K ceramic body and the coating material is said to be the cause of the capacitor's strength.

The capacitor is a 0.005 MFD, 500v d-c unit, and will meet RTMA standards. Test voltage is 1,300v d-c; leakage resistance over 7,500 megohms; and a power factor of less than 2.5 percent.

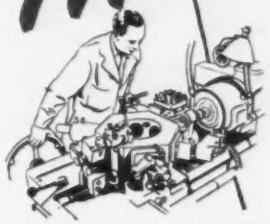
Jeffers Electronics, Inc., Dubois, Pa.

A NEW POWER SUPPLY UNIT is rated at 0-30 v and 15 amp continuously with a ripple of less than 1 percent, and a voltage regulation of $\pm\frac{1}{2}$ v from no load to full load. Known as the model MS168B, it uses selenium rectifiers, and a magnetic amplifier circuit for voltage regulation. The cabinet features 4½ in. rectangular meters and a continuously variable transformer. Suitable for either 19 in. rack panel, or bench cabinet mounting. Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.

KNOWN AS A FUSISTOR, a new resistance unit is a combination resistor and fuse that will operate as a resistor only, under a normal electrical load. When it is subjected to an overload of current, it will hold the overload for a predetermined time, then melt or burn out.

The fusistor can be built to carry an overload for a minimum of 20 sec., then fuse or burn out within the next 30 seconds. The overload time lag can be established within closely controlled minimum and maximum time limits. There is no flame or spark at the moment of fusion. Milwaukee Resistor Co., 700 West Virginia St., Milwaukee 4, Wisconsin.

METAL-WORKING'S *Master Clutch*

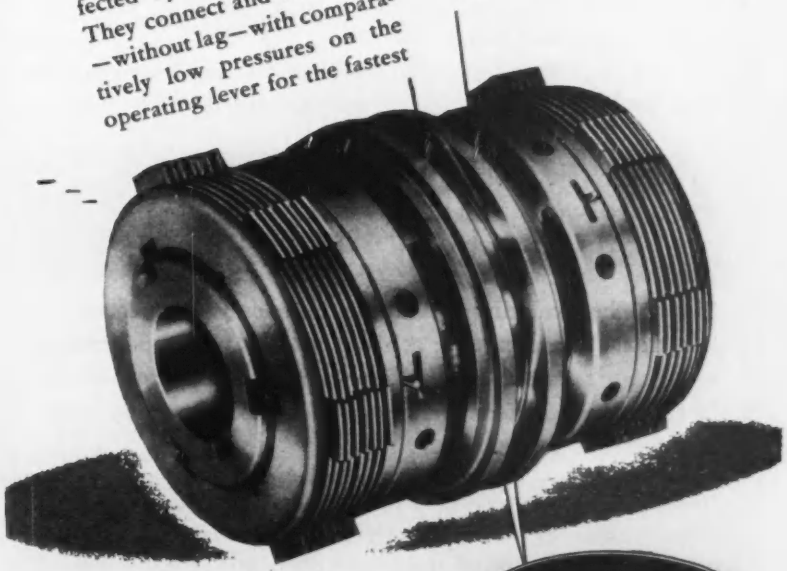


It would be interesting to speculate on how much of America's total metal-working production is on machines which are "put to work" through Twin Disc Machine Tool Clutches. For these units have so well proved their efficiency that almost every leading machine tool manufacturer in the country employs them on one or more models.

These clutches are unaffected by centrifugal action. They connect and disconnect —without lag—with comparatively low pressures on the operating lever for the fastest of work cycles. They're conservatively rated to assure the longest of wear life, with simple, single-point adjustment when needed.

Moreover, they are designed to work in very limited space and transmit, with positive clamping action, a high amount of torque. For all the reasons why Twin Disc Machine Tool Clutches—duplex or single, oil type or dry type —are the industry's standard, write today for Bulletin No. 134-A.

Fast, lag-free operation, in a compact, high torque capacity clutch is assured with Twin Disc Oil Type or Dry Type Machine Tool Clutches, offered in a complete range of capacities.



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Simple chemical dip; immersion time only 10 seconds to 2 minutes; no sealing dip; color is clear or yellow depending upon your requirements; salt spray resistance equivalent to 20 to 30 minutes of anodizing, eliminates need for costly racks and electrical power.

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MEETINGS

August 11-13

SOCIETY OF AUTOMOTIVE ENGINEERS—West Coast Meeting. Fairmont Hotel, San Francisco, Calif.

August 12-16

PHOTOGRAPHIC SOCIETY OF AMERICA—Technical Division Meetings. Hotel New Yorker, New York, N. Y.

August 20-28

INTERNATIONAL CONGRESS ON THEORETICAL AND APPLIED MECHANICS—Istanbul University, Istanbul, Turkey.

August 27-29

WESTERN ELECTRONIC SHOW AND CONVENTION — Municipal Auditorium, Long Beach, Calif.

September 4-5

NATIONAL CONFERENCE ON INDUSTRIAL HYDRAULICS — Hotel Sherman, Chicago, Ill.

September 8-10

NATIONAL STANDARDIZATION CONFERENCE, SPONSORED BY AMERICAN STANDARDS ASSOCIATION—Museum of Science and Industry, Chicago, Ill.

September 8-11

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—Fall Meeting, Sheraton Hotel, Chicago, Ill.

September 9-13.

NATIONAL CHEMICAL EXPOSITION —Chicago Coliseum, Chicago, Ill.

September 10-12

PORCELAIN ENAMEL INSTITUTE—Annual Shop Practice Forum, University of Illinois, Urbana, Ill.

September 11-14

PACKAGING MACHINERY MANUFACTURERS INSTITUTE—Annual Meeting. The Homestead, Hot Springs, Va.

September 29-October 1

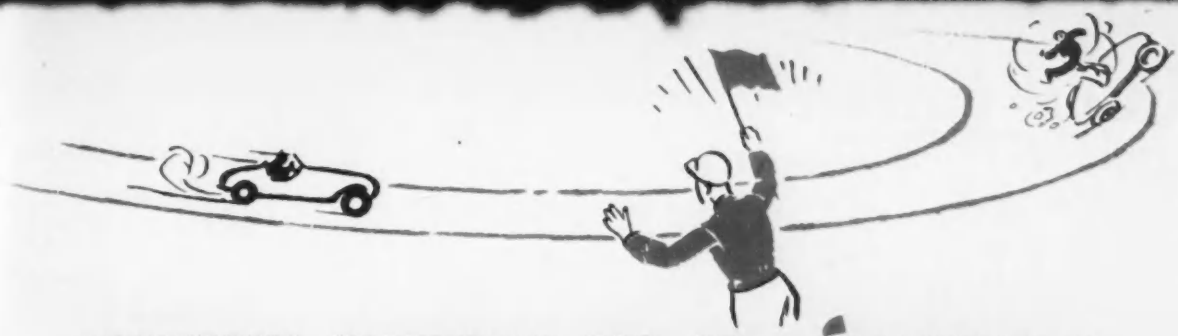
NATIONAL ELECTRONICS CONFERENCE—Eighth Annual Conference, Sherman Hotel, Chicago, Ill.

October 20-24

NATIONAL METAL EXPOSITION AND CONGRESS — Convention Hall, Philadelphia, Pa.

October 22-24

PORCELAIN ENAMEL INSTITUTE—21st Annual Meeting. Greenbrier Hotel, White Sulphur Springs, W. Va.



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OVERLOAD RELEASE CLUTCH

The tremendous expansion in the use of high production automatic machinery, especially in the bottling, packaging, labeling, wrapping and kindred fields, calls for added protection thru safety controls in power transmission equipment.

For this purpose we offer the Maxitorq floating disc Overload Release Clutch which automatically and instantly releases when the nature of an overload is either a heavy shock or suddenly applied load of a magnitude substantially greater than normal driving load. In such instances the machine mechanism may be clogged, products damaged and operator injured...all of which means expensive down-time.

The Overload Release Clutch performs most effectively and prevents heavy overload destruction. When jammed condition is cleared the clutch is re-engaged and operation continues. Simple fingertip adjustment sets the clutch to transmit normal running load. For original equipment, specify Maxitorq. There are six standard capacities, ¼ to 5 H.P. @ 100 r.p.m.

New catalog gives complete engineering specifications; shows complete line of standard clutches and driving cups.

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At LESS COST

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Sans, Souci

Ad Libbing by the Editor

Years ago I worked in a steel plant where they had an exceptional man for superintendent. This man was not only a great organizer but also had some highly unusual methods for handling men and situations. As near as I have ever been able to figure it out, he made the man himself decide that the way the super wanted it done was the best way.

One day Bill the boss tool maker came up to F. V. with an expanding arbor that the tool room had just made. "How's this?" asked Bill as he handed over the expanding arbor to F. V. who scarcely looked at it, handed it back, curtly said, "No good!" and quickly walked away.

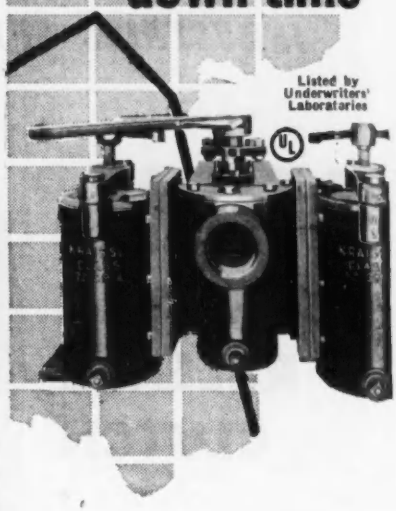
It was not until almost a week later that I had the chance to ask F. V. about his abrupt manner in telling Bill that the expanding arbor was "No good" while in fact F. V. had not looked at it closely enough to tell what it was. F. V. chuckled.

"George", said F. V., "When Bill asked me, 'How's this', I knew right away that he was not proud of that job. That being the case, I wasn't going to give it my stamp of approval. If a man can't come to me with a job he has done and throw out his chest and say it is the best job of its kind, it means to me that that fellow himself does not think much of it. That's why I told Bill the arbor was no good. And it wasn't good. You should see the new one he delivered to me yesterday with a gleam in his eye and exclaiming, 'This is it and even you will be surprised.' And it was a swell job."

Of course there is such a thing as being too curt and abrupt. A meticulous engineer who prided himself on "knowing all the answers" was driving his car through Canada. He decided that he should get his crankcase drained. He knew that his car took eight quarts of oil so he told the garage man to simply dump in eight quarts. The garage man demurred and said seven quarts would be plenty. But the meticulous engineer said rather abruptly, "I know how much oil this car takes." He was given eight quarts. From then on, the car didn't run quite right. Finally the fellow got back home and took the car to his favorite garage. The garage man wanted to know why he had flooded the engine with oil. He protested that he put in only eight quarts and that was the

• SINCE 1926 • in the application, design and mfg. of pumps — separators — hydraulic accessories.

cut "down time"



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HACKENSACK, N. J.

289 Williams Ave.

amount specified in the service manual.

The meticulous engineer was wrong again. The Canadian service station man put in eight Imperial quarts which is equal to about nine and one-fourth U. S. quarts.

Again there are those who talk out of turn. I remember during the depression days Big Frank had loaned a temporarily ex-wealthy man about $15,000 on a mortgage on his home. For some reason or other, maybe the worries of the depression had something to do with it, the ex-wealthy man started to labor under the delusion that Big Frank would call the mortgage on the first interest date. He became so obsessed over it that he talked about it to anyone who would listen and called Big Frank a Shylock, loan shark, and lots more.

I happened to be in Big Frank's office when his male secretary was telling him about it. The secretary had heard all about it over at the club. And he urged Big Frank to "give that cockeyed guy the works". Big Frank would not listen and did nothing. The next week the secretary started all over again. Finally Frank said, "Get that man on the phone."

One end of the conservation ran something like this:

"Yes. What's this you're saying about me? Why do you call me all those names? What did I do to you?"

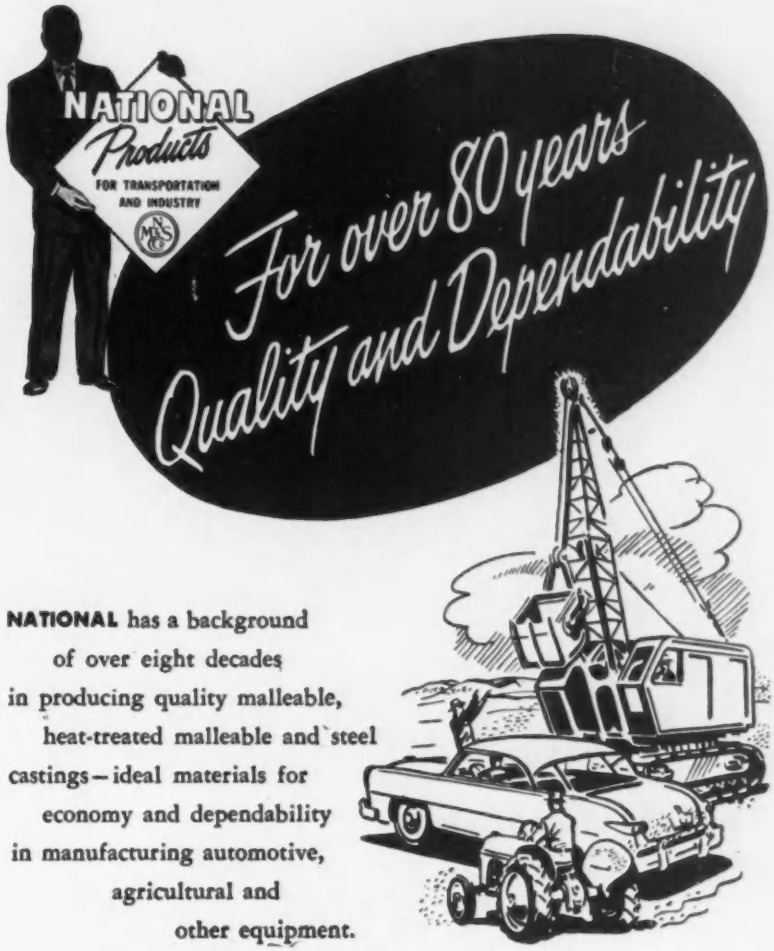
After a short silence:

"Now see here, you did say something. My secretary says so and he doesn't lie."....."So you did say it!"....."Did I say I was going to call your mortgage? I own that mortgage so it's only what I say that counts."....."Well I'll tell you what I am going to do. I give mortgages to two kinds of people. The one kind are the good people who like to be nice. They go to church, they are good citizens, and people like them. You can trust them whether they have money or not. Those kind, I charge five percent.

"Then there is the other kind of people. They are not nice. They say mean things, maybe because they don't go to church. Anyhow you feel you can't trust them entirely. Those kind I charge six percent. You've been paying five percent. From the next interest date on, you pay six.'"

The secretary was disappointed. "Why don't you call his mortgage?" he asked.

"John", said Big Frank, "That would have proved the guy was right. But this way, he will feel so bad about what he said that he will come and apologize and then I will make him my friend for life." — G. F. N.



NATIONAL has a background of over eight decades in producing quality malleable, heat-treated malleable and steel castings—ideal materials for economy and dependability in manufacturing automotive, agricultural and other equipment.

NATIONAL's unparalleled experience—coupled with a continuing metallurgical research program, rigorous quality control standards, and completely mechanized foundries in strategically located cities—is at your disposal.

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ENGINEERING ABSTRACTS

Properties of Some Heat-Resistant Adhesives

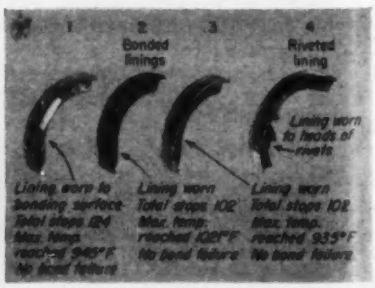
Abstracted from "Properties of Some Heat-Resistant Adhesives" by C. W. Roush and A. J. Kearfott, Research Laboratory Division, General Motors Corp., Detroit, Michigan. *Mechanical Engineering*, May, 1952.

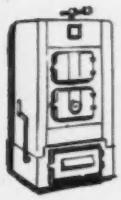
IN RECENT YEARS, heat-resistant adhesives have replaced rivet and other mechanical means of joining materials in several applications that require good strength and performance at elevated temperatures. The most familiar and perhaps the most severe application in the automotive industry is bonding linings to brake shoes. The adhesives also are being used in automotive transmission parts.

In spite of the severity of the service that must be withstood in automotive application, particularly in brake bonding, good results have been obtained with adhesives.

The following discussion covers actual production parts made by General Motors Divisions. The brake shoe is bonded with an adhesive in tape form. The tape is tackified and applied to the bottom surface of the lining. The lining is then placed against the brake shoe in a fixture which is passed through an oven for curing. The band used is a clutch assembly band, and the friction surface is bonded to the steel with a thermosetting resin. The clutch disks have the faces bonded with a similar adhesive in cement form. The thermosetting adhesives used for these parts are highly oil resistant (also to hot oils), and their application in transmission parts has resulted in satisfactory and, in many cases, improved service life.

The performance of the thermosetting adhesives used in the brake-bonding application is illustrated in Fig. 2. Three brake shoes with bonded linings that were subjected to a brake dyna-





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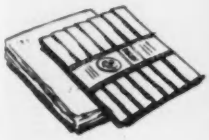

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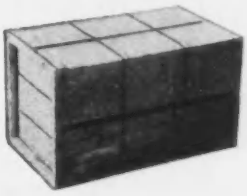

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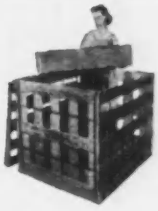

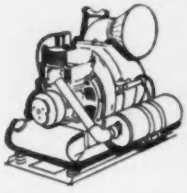

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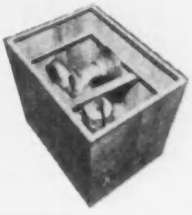

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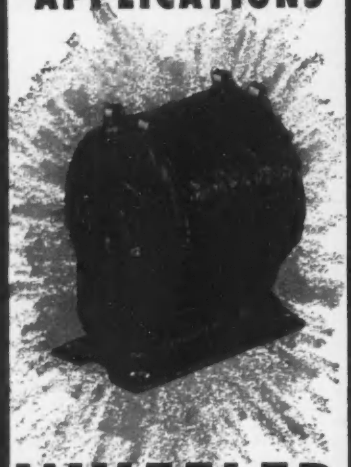

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mometer test and one shoe with a riveted lining taken from service are shown. The brake-dynamometer drum was insulated to subject the bonded shoes to extraordinary temperature conditions. The braking pressure was 500 psi and was applied repeatedly to brake the drum speed from 70 mph to 10 mph. Friction produced the temperatures shown below each shoe. Shoe No. 1 was subjected to 124 braking actions and, as can be seen, the lining has worn away to the bonding surface. However, there was no sign of a bond failure, although a temperature 945 F was reached. Shoes Nos. 2 and 3 were subjected to 102 stops, and temperatures of 1021 F and 935 F, respectively, were attained. In neither case did the adhesive show signs of failure.

An apparent advantage is obtained by the use of an adhesive in that application which can be seen by comparing shoes Nos. 1 and 4. On both shoes the limit of service life has been reached. On shoe No. 4 the rivet heads have limited the service life of the lining. Complete use of the lining was obtained by bonding with an adhesive as is shown by shoe No. 1.

The heat-resistant, high-strength, thermosetting adhesives are suitable for a wide range of application since they can be used to join a variety of materials. Facing material on the clutch disks varies from the cork-and-paper type to a metallic-type facing. The adhesives also have shown good adhesion to many metals.

Types of Adhesives

There are two general types of adhesives, one based on thermosetting resins and the other on thermoplastic resins. Both types of adhesives generally require heat to form a bond although there are exceptions. The difference between the adhesives lies in their behavior at elevated temperatures. A thermoplastic adhesive is rigid at low temperatures and becomes soft and pliable at high temperatures. A thermosetting adhesive does not change its state after it is once cured.

The thermosetting adhesives are employed in most applications requiring heat resistance and strength at elevated temperatures.

This discussion is based upon heat-resistant adhesive compounds that consist of a thermosetting resin, an oil-resisting elastomer, and various other chemicals that act as activators for the resin, curing agents for the elastomer, and as anti-oxidants. At a rule the elastomer imparts better impact strength and resiliency to the cured bond while the other ingredients shorten the time of cure and give the

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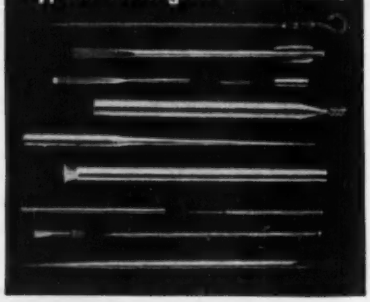

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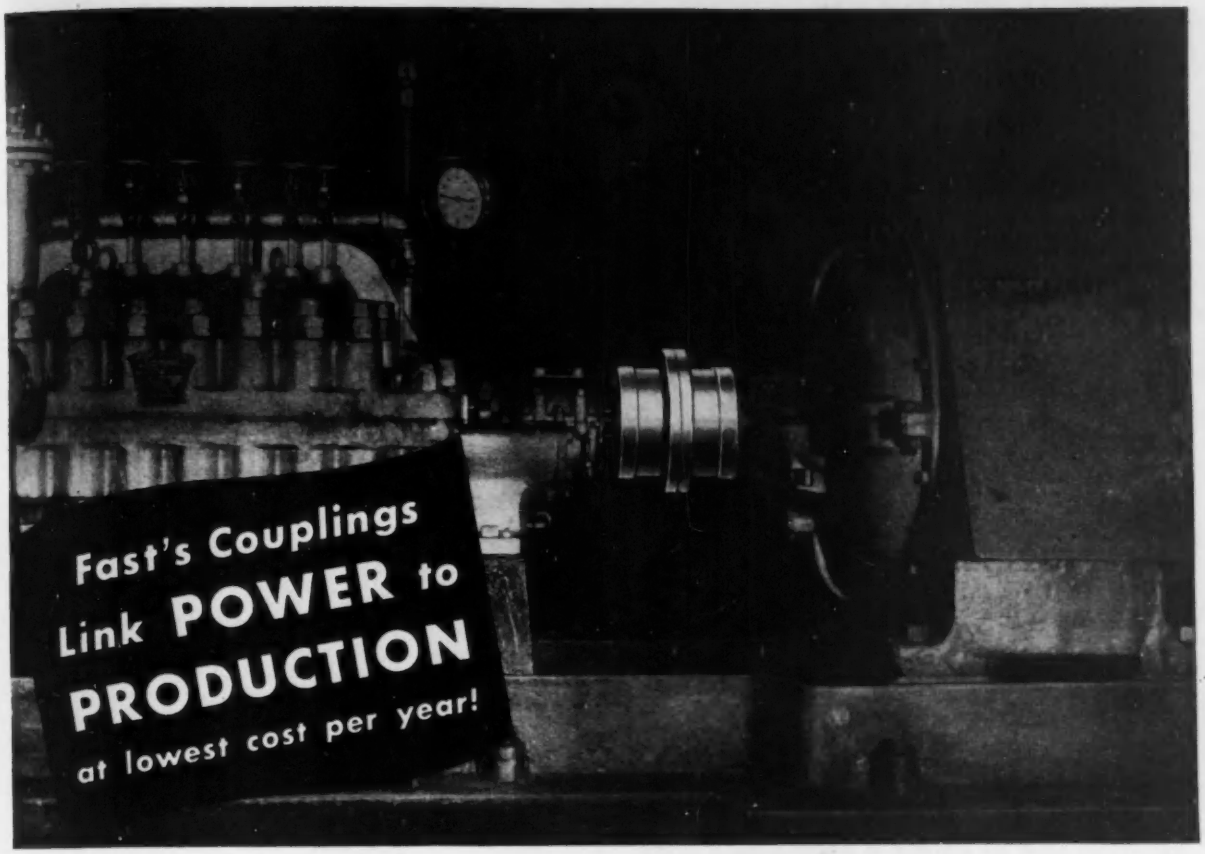

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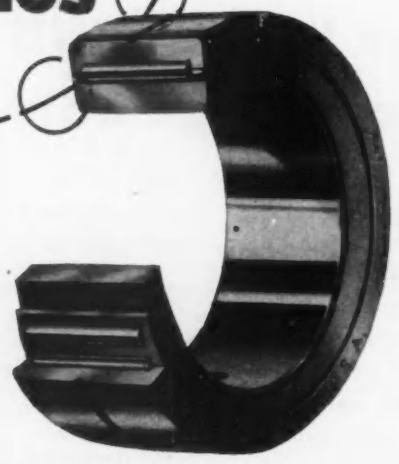

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adhesive its optimum properties. The elastomer in such a compound provides a base for the powdered resin when the adhesive is used in tape form.

The two general forms in which the adhesives are used are tape and cement.

Storage Life of Uncured Adhesives

One of the main problems encountered in the use of adhesive tape is the relatively short storage life of the uncured tape especially at temperatures over 100 F which occur frequently in normal storage places. It is a safeguard when using adhesives to maintain cool storage temperatures in the range of 40 to 60 F and a small inventory of the uncured adhesive.

Curing Procedure

The thermosetting-type adhesives require heat and pressure during their cure to obtain a good bond. In general, the curing temperature will range from 350 F to 450 F and the pressure from 50 to 300 psi.

The time required for a satisfactory cure will depend upon the adhesive being used. Variations in compounding will affect the time required and a series of tests are usually run to obtain the time required for the optimum or adequate properties. Often a compromise is necessary between the properties desired and the economical cure time.

Properties of Cured Bond

The bonds obtained with a phenolic-elastomer adhesive after proper curing exhibit high tensile strength, good shear strength, and good heat resistance.

The tensile strength of steel-to-steel bonds after proper curing can reach 3000 to 4000 psi with little difficulty. Table I presents the tensile strengths of four representative adhesives that have been given a cure of 60 min at 400 F under 200 psi pressure. The adhesives are all phenolic-elastomer blends. The tensile strength decreases as the temperature increases, which is a general for this type adhesive.

The shear strength of the phenolic-

Table I—Tensile Strength and Its Variation With Temperature of Some Thermosetting Adhesives

	Adhesive			
Tensile strength, psi:	1	2	3	4
At room temp...	4,200	4,000	4,900	3,200
At 200 F.....	.....	2,200	.....	.....
At 300 F.....	1,480	1,500	1,360	.....
At 400 F.....	900	1,000	500	.....
At 500 F.....	100	400	10	900

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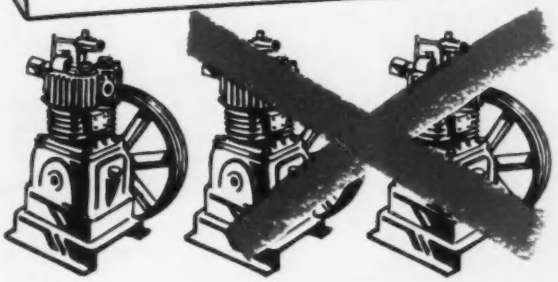

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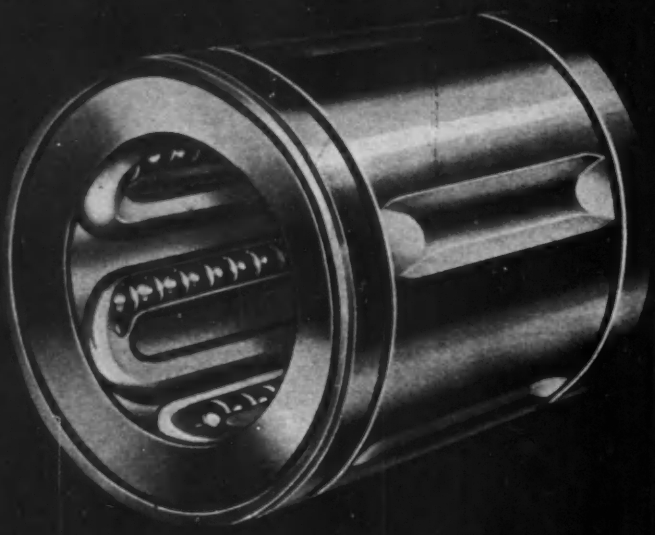

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elastomer adhesives exceeds 1,000 psi at room temperature. Table II presents test results that are indicative of the shear strength of three adhesive bonds on a production-type lining and brake shoe.

The effect of temperature on the shear strength is the same as it was on the tensile strength.

The upper temperature limit for an adhesive seems to depend somewhat on the materials that are being joined. The results previously mentioned indicate that bonds between a material such as brake lining and steel will withstand higher temperatures than steel-to-steel bonds. Laboratory tests also have indicated such an occurrence

Table II—Shear Strength and Its Variation With Temperature of Some Thermosetting Adhesives

Phenolic-elastomer blends; lining to brake shoe bonds

Shear loads applied at 15 deg angle given on 1 in. Segment of lining measured along circumference of brake shoe. Width of lining approximately 1¾ in.

	Adhesive		
Shear load, lb:	1	2	3
At room temp.....	1,820	1,480	1,700
At 300 F.....	560	530	650
At 500 F.....	300	325	320

Note: All failures were in the lining 95 percent minimum

although the tests have not given results comparable to those obtained on the brake dynamometer. It is thought that the more heat-resistant bonds obtained with the brake-lining material result from venting the gaseous products through the relatively porous lining during the curing cycle. The greater penetration into the lining by the adhesive and the possible compatibility between the resins of the adhesive and the lining also act to reinforce the bond.

It will be noticed in Table III that the change in static tensile load from 50 to 300 psi has not affected the temperature at which the bonds fail to any great extent. For adhesive No. 1, the temperatures are almost identical and although adhesive No. 2 shows a slight trend, the experimental errors in this test together with the natural variations in adhesive bonds tend to make this trend inconclusive.

Steel-to-steel bonds of phenolic-elastomer adhesives have shown static fatigue lives of over 2,500 hr at 400 F under a 200 psi static tensile load. However, the fatigue life decreases as the temperature increases. For ex-

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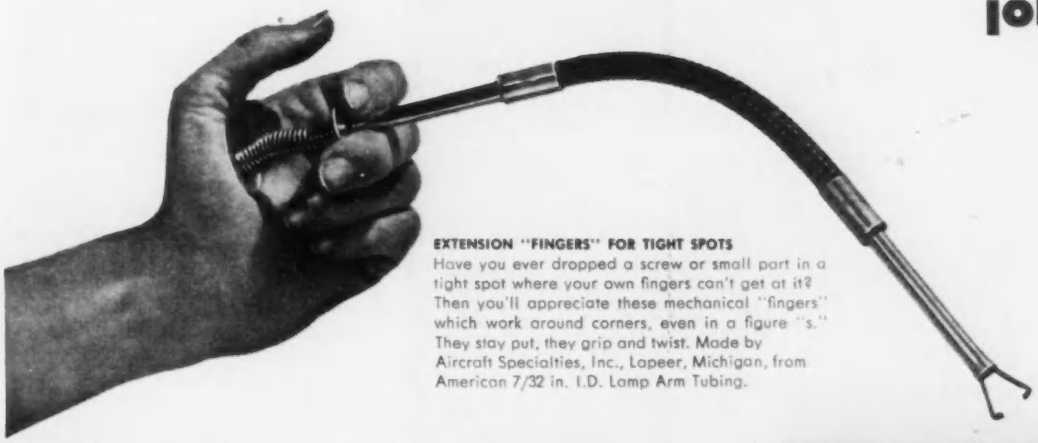

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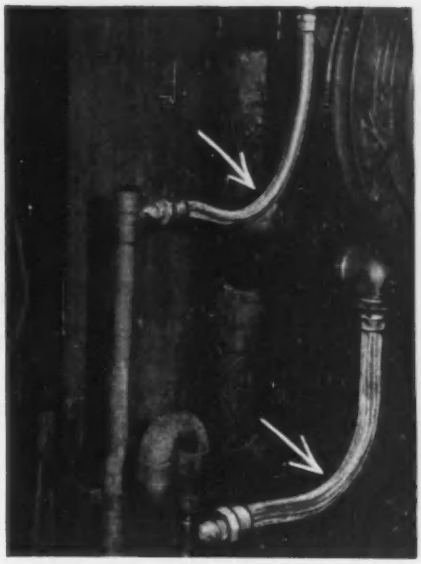

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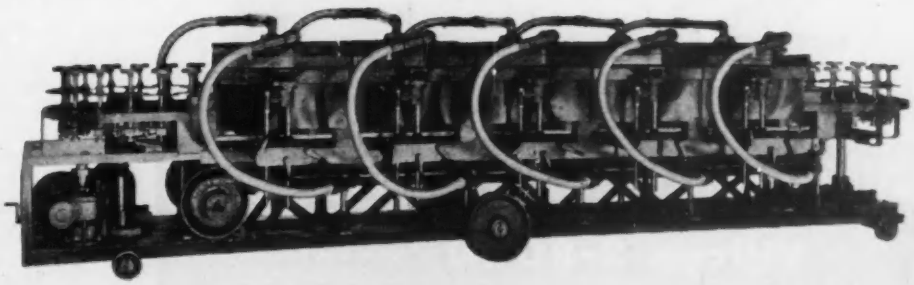

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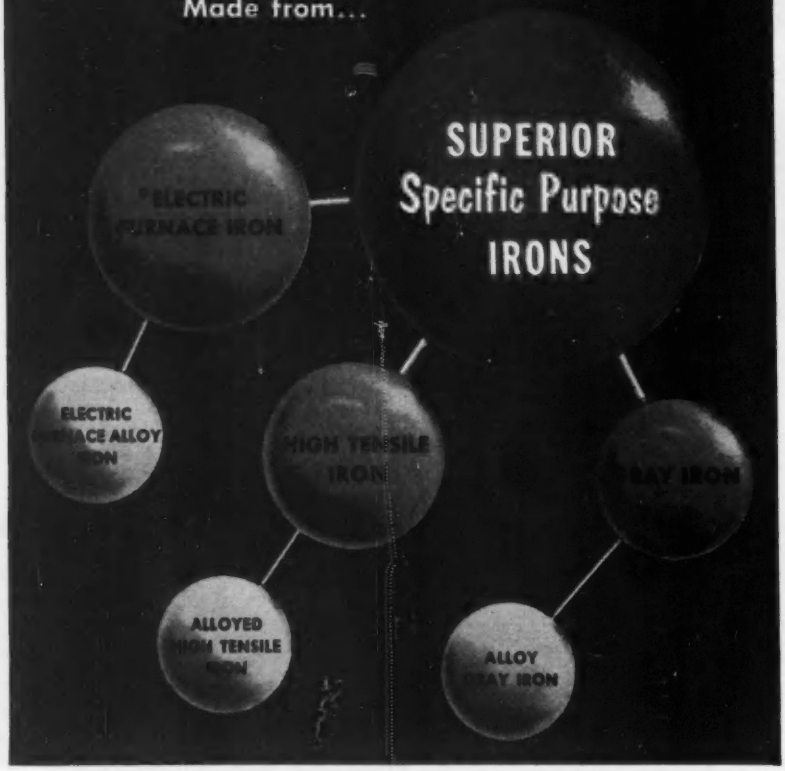

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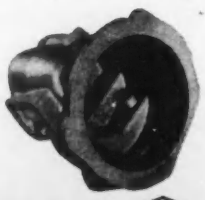

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Table III—Effect of Static Load on Failing Temperature of Thermosetting Adhesives

Phenolic-elastomer adhesive tapes; steel-to-steel bonds

Failing temp, deg F

	Adhesive	
Static tensile load, psi	1	2
50	620	574
100	640	568
200	602	552
300	604	544

ample, an adhesive that will last for months at 400 F under a 200-psi tensile load may fail in a few hours at 600 F and a 25-psi tensile load. The static fatigue life of a cured thermosetting adhesive is essentially indefinite at temperatures below 300 F under a 200-psi tensile load.

Industry Training for Co-Op Engineering Students

Abstracted from "What Type of Training Should Industry Provide for Co-Op Engineering Students" by Thomas Hand, Corhart Refractories Co., Louisville, Kentucky, *Journal of Engineering Education*, March 1952.

In the 1930's, students taking cooperative engineering education were considered as cheap labor and were assigned jobs lacking in engineering aspects. Today, most labor unions look upon the co-op student as an infringement on their rights. They feel that these students are taking bread from the mouths of union members. As a result, cooperative programs are being limited in actual use.

Management must develop a training program that will take advantage of the experience-getting opportunities offered by cooperative education and at the same time satisfy union demands, or cooperative engineering education is useless.

Ideally, such an industry training program would combine engineering and executive training including these subjects:

Engineering Training

1. Skills of the industry
2. Related Training
   a. Math and shop problems
   b. Science of the industry
   c. Blueprint reading
   d. Product knowledge
   e. Manufacturing processes
   f. Maintenance of equipment
3. Job Methods
4. Safety and Housekeeping

Remember when...

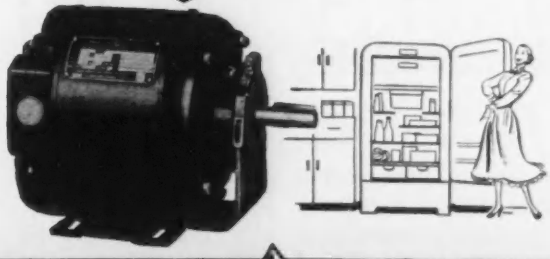
Refrigeration meant a cake of ice?

Perhaps those were the "good old days" . . . but who would trade the refrigerator found in today's average American home for an old-fashioned ice-box?

Electrical home appliances have eliminated countless chores for modern housewives. Today's refrigerator, for example, requires practically no attention—because it can be powered by an Emerson-Electric hermetic motor. True to a 62-year tradition of precision manufacture, each Emerson-Electric hermetic motor is carefully built, tested, and sealed for shipment, under accurately controlled atmospheric conditions.

In addition to hermetic motors in horsepower ratings from ⅛ to 15, Emerson-Electric offers a complete line of standard motors from 1/20 to 5 h.p. for use on equipment for the home, the farm, in business and industry. Your inquiry is invited. THE EMERSON ELECTRIC MFG. CO., St. Louis 21, Mo.

MODERN LIVING IS POWERED WITH ELECTRIC MOTORS



EMERSON-ELECTRIC'S unique *Twin-gineering* SERVICE solves your power problems

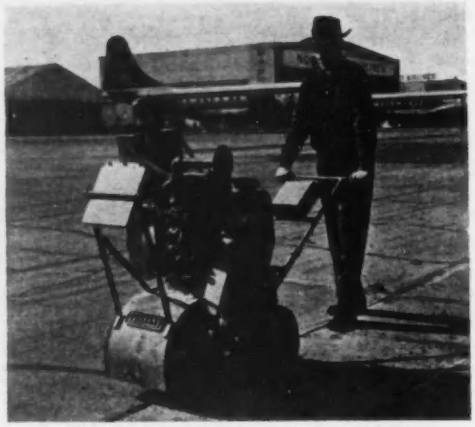
Our engineers are eager to work with yours in designing and providing the correct motor for contemplated new or improved appliances or equipment. "TWIN-GINEERING" saves costly engineering "back-tracking," and may suggest short cuts and product improvement. Write today for Bulletin No. M120.

EMERSON ELECTRIC
MOTORS • FANS APPLIANCES

LEADERS IN THE FAN AND MOTOR INDUSTRY SINCE 1890

WISCONSIN-Powered Joint Cleaner Helps Prepare WRINKLE-FREE Runways

POWER TO FIT THE MACHINE — POWER TO FIT THE JOB



Powered by a 13 hp. Model TF 2-cylinder Wisconsin Heavy-Duty Air-Cooled Engine, this Model "G" Tennant joint cleaner, manufactured by the G. H. Tennant Co., Minneapolis, Minn., prepares airport pavement joints for re-sealing. The machine routs out shrunken old seal, pebbles and dirt, refacing side-walls at the same time.

Helping to prepare smooth, "wrinkle-free" runways is another typical power service application in which Wisconsin Air-Cooled Engines fit both the machine and the job.

You can't do better than to specify "Wisconsin" for any purpose that requires dependable engine power within a 3 to 30 hp. range.

MOST H.P. HOURS

WISCONSIN MOTOR CORPORATION

World's Largest Builders of Heavy-Duty Air-Cooled Engines

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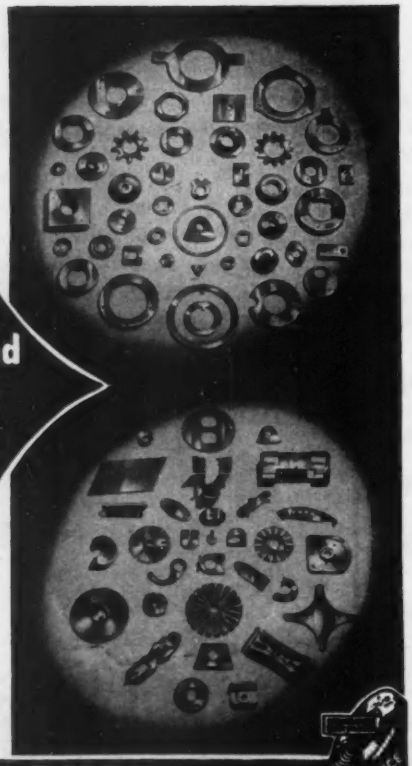

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5. Waste elimination
6. Engineering economy
7. Research—new products
8. Research—new techniques
9. Sales Techniques

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2. Company Policy
3. Company Morale
4. Job Relations
5. Promotion Opportunities
6. Labor Relations
7. Economics
8. Business Ethics
9. Safety Standards
10. Labor Contracts
11. Law (corporation and labor)
12. Forecasting new developments
13. Research Methods
14. Public Speaking

Admittedly such a training program could take years to do a proper job. But here is how the elements were put to work at the author's company.

It was decided that four departments require some engineering skill: production, engineering, and maintenance, research and development, and sales. And the training program was broken into four quarters.

In the first quarter, the student is assigned to the research and development department. Assignments here include:

1. Control work in processes or products
2. Routine testing of products
3. Physical measurements on new products
4. Preparation of laboratory samples
5. Gathering data from experiments
6. Gathering data from records

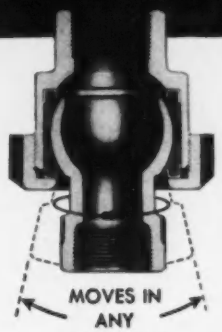
About 25 percent of the student's time is spent performing at his job; the remaining 25 percent is devoted to plant inspection trips and discussions of processes and industry problems.

During the second quarter, the student works in plant engineering and maintenance. His on-the-job assignments include:

1. Drafting
2. Plant layout and planning
3. Testing of new equipment
4. Maintenance of production equipment
5. Blueprint checking
6. Simple equipment Design Problems
7. Preparing Bills of Materials

At this time, training in human relations is started, and the student is invited to attend supervisors' meetings and to join the company's Management Club. Occasionally an advanced student is permitted to work on a

BARCO



1. **MAXIMUM FLEXIBILITY.** Up to 40° side flexibility with 360° rotating movement.
2. **CHEMICALLY INERT GASKETS.** Barco offers a choice of seven types of gaskets including No. 11-CT for corrosive service. No lubrication required.
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4. **STAINLESS STEEL BODIES.** Also regularly furnished in Malleable Iron, Steel, Bronze, Aluminum, and Magnesium. Other special alloy joints to order.
5. **PRESSURE-SAFE! FIRE-PROOF!** Unequalled for SAFETY where flexible connections are required.
6. **MANY STYLES AVAILABLE.** Angle or straight; threaded or flanged connections. For pressures to 6,000 psi; temperatures to 1000°F. 15 different sizes, ¼" to 12".

ASK FOR YOUR COPY
OF BULLETIN No. 215

Flexible BALL JOINTS

— when you need movable joints in piping handling

CHEMICALS

THE above photograph shows BARCO BALL JOINTS used to provide flexibility in Nitric Acid Tank Car Loading Lines at the Joliet, Ill., Arsenal. This is but one of many installations in the chemical industry where Barco joints are used to allow movement in piping conveying acids, alkalies, and solvents — as well as steam, air, oil, gas, or water.

BARCO BALL JOINTS offer many advantages over ordinary types of joints or flexible connections. When you want to be sure of getting SAFE, long-lasting, trouble-free installations, specify BARCO! Ask our engineers for recommendations. Worldwide Sales and Service. BARCO MANUFACTURING Co., 1827H Winnemac Ave., Chicago 40, Illinois. *In Canada:* The Holden Co., Ltd., Montreal.

BARCO

THE ONLY TRULY COMPLETE LINE OF FLEXIBLE BALL, SWIVEL, SWING, AND REVOLVING JOINTS

WHAT ARE YOUR INDIVIDUAL NEEDS FOR A

HEAT EXCHANGER COOLER or CHILLER

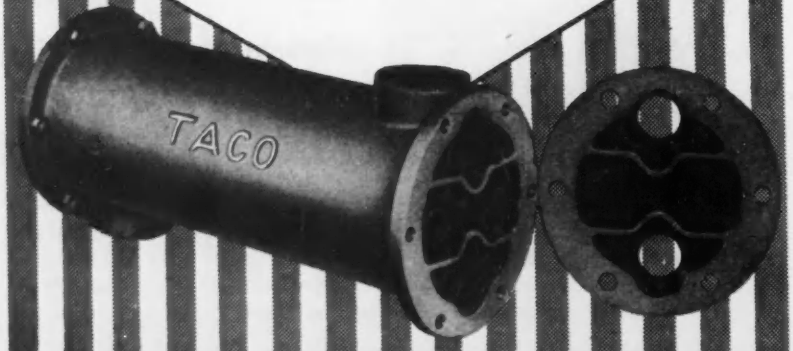
WHAT SHAPE? WHAT TYPE? WHAT MATERIAL?

for heating or cooling...

WATER • HYDRAULIC OILS • LUBRICATING OILS
COOLANTS • CUTTING OILS • OTHER LIQUIDS

Our engineering department will gladly assist you, just as it has numerous other organizations, in design and selection of proper exchanger for your particular requirements.

A heat exchanger specialist from the factory is immediately available. Just call Providence, R. I., GAspee 1-2600, wire or write.



Illustrated is just one of more than 100 different shapes we are making as component parts for manufacturers.

Taco

TACO HEATERS, INCORPORATED
132 South [illegible], Providence 3, R. I.

project alone. In this case, he must prepare monthly progress reports and a final report.

The third period is spent in the production department. By this time, the student is fairly well acquainted with the company and can do these assignments:

1. Time Study
2. Record Clerk
3. Assistant to Department Supervisor
4. Special production problems
5. Observer for quality control
6. Orderchecking before shipment
7. Inventory control
8. Stock Room Clerk

While in the production department, the student gets training in labor relations, labor contract, how to give orders, how to descipline employees, and how to get along with people.

The student's final training period is with the sales department. This assignment rounds out his experience with the company. Typical schedule is as follows:

1. Drafting
2. Equipment Design
3. Product Installation Drafting
4. Product design
5. Bill of material preparation
6. Field Trips
7. Customer Contact
8. Observer of Product Installation

By the time the student has completed these four periods of training and finished his college training, he has been well screened by the company. And they are in a position to know definitely whether the student will fit into a key spot.

Trends in Gas Turbine Engine Materials

Abstracted from "Trends in Gas Turbine Engine Materials". Excerpts from paper by R. H. Thielemann, J. C. Mertz, and W. P. Eddy, Jr.; *SAE Journal*, April, 1952.

STRATEGICALLY IMPORTANT METALS are the key to jet engine performance; if large numbers of jet engines are to be built, these metals must therefore he utilized as efficiently as possible.

There are several possible methods of approach to the problem. Two of them are:

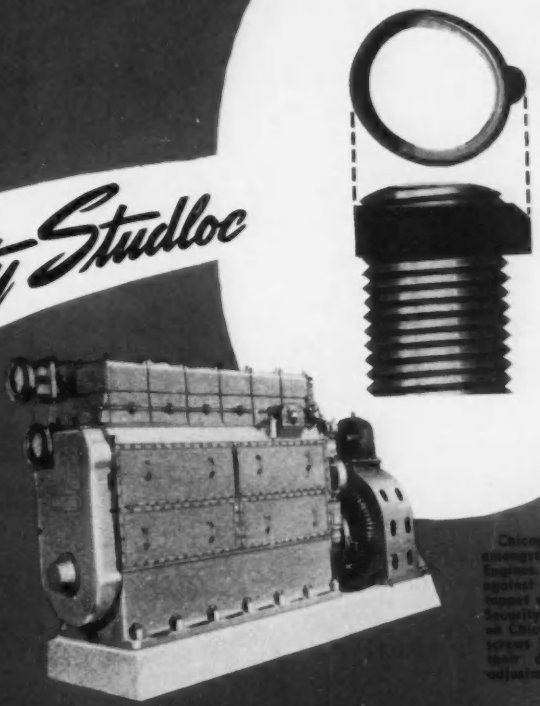
1. Substitution of protectively coated carbon or low-alloy steels for stainless alloys in parts which operate at relatively low temperature.

2. Development of less critical super-alloys having high-temperature properties equal or superior to those of existing alloys.

Success in some applications of each of these methods may of course be

A SPECIAL fastener for special problems

Security Studloc



Chicago Pneumatic Tool Company amongst other things builds Diesel Engines. Holding the adjustment against the vibration present on the tappet adjusting screws was a problem. Security Studlocs have been in service on Chicago Pneumatic tappet adjusting screws for some time and have proved their dependability for holding the adjustment setting.

Here is the Security Locknut! It provides an unqualified answer to several fastener problems. Grueling tests by various notable sources have demonstrated that Security Locknuts cannot work loose regardless of vibration that would destroy the bolt. Security Locknuts can be removed and re-used any number of times. If you have a fastener problem, quickly "Locknut."

SECURITY has solved the problem of keeping adjusting screws, bolts and studs *where you want them!*

The Security Studloc can be adapted to provide a positive lock in counterbores and housings or it can be keyed into work to serve as a simple lock nut.

The Security Studloc will hold its position on a bolt, adjusting screw or stud in the face of vibration that will destroy the bolt. It can be readjusted, removed and replaced any number of times without distorting or damaging the bolt and without materially reducing its holding power. All load is carried by the threads of the tapped hole not by the Studloc.

The Security Studloc is a simple, elliptical, heat treated, spring retainer of the highest quality spring steel possible to obtain. Forcing it into "round" creates a gripping power that defies any attempt to move it except by design. An ear on one side permits keying the Studloc into the plate, base or housing.

Security Studlocs are serving in locking tappet adjusting screws, cylinder head studs, engine through bolts, flange screws and in solving other difficult problems where bolts or studs must be kept tight. They are available in bolt sizes ¼ in. to 3 in.

If you have a fastener problem that begs us to solve it! Send the coupon.

SECURITY LOCKNUT CORPORATION
North Ave. and 15th Ave., Melrose Park, Ill.

SPECIAL OFFER Ask for a Security Thread Tolerance Chart. Spin the dial and you have your thread tolerance figures.

Security
The Nut You Can't Shake Loose

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Please send me without obligation:

☐ One of your Thread Tolerance Charts.

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SWITCHES *that Swim*

Fishing for waterproof toggle switches? Then get your hooks into these! They actually open and close electrical circuits underwater . . . function perfectly from 65° below zero to 165° above . . . defy salt spray . . . and withstand shock and vibration!

COMPETENT ENGINEERING SERVICES

Riverside engineers developed the prototype of this switch to meet aircraft requirements, then modified it for present applications. It's being furnished now with ratings from 20 to 200 amperes, in toggle arrangements of momentary ON or OFF and stationary ON or OFF, with one or two hole mounting. Switch body is encased in a molded rubber compound developed to meet military specifications. Waterproof lead wires are vulcanized into the rubber case and become integral parts of the assembly, as does the switch mechanism itself. Waterproof connectors are assembled to the leads when required.

EXPERIENCED ASSEMBLY PERSONNEL

Perhaps now, or with further modification, this switch can put a "plus" into *your* product! Additional applications, better performance, "built-in" safety for an appliance or power tool . . . or to solve some other problem for you. Consult our engineers. They'll be glad to give you design and manufacturing recommendations for *any* intricate electrical devices or assemblies. Send specifications, prints or samples . . . today!

POSITIVE CONTROL OVER QUALITY

COMPLETE PRODUCTION FACILITIES

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impossible without re-design of engine components.

In general, if stresses are high and if temperatures encountered are much in excess of 1000 F, the austenitic chromium-nickel type alloys must be specified. For lower temperatures, choice between ferritic stainless steels and low-alloy steels is often dictated by creep values and requirements of corrosion resistance. Where the necessary corrosion resistance can be maintained under operating conditions by application of protective coatings, it is frequently possible to conserve appreciable quantities of chromium by specifying plain carbon or low-alloy steels. Attempts are being made to develop protective coatings which will make it possible to use heat-treatable carbon and low-alloy steels for all steel parts of jet engines which get no hotter than 900 or 1000 F.

For non-rotating parts not subject to abrasion, such as brackets and internal supporting components, ample corrosion resistance is afforded by certain silicone-vehicle aluminum paints, provided temperatures do not exceed 400 or 500 F.

Where abrasion and other mechanical abuse are factors, excellent corrosion resistance can be obtained by application of sprayed aluminum, provided the thick coating does not adversely affect performance and temperatures do not exceed approximately 600 F. An aluminized outer burner casing formed of AMS 5040 (SAE-1010) steel (Fig. 1) is an example of an advantageous use of this type of coating. Many thousands of similar aluminized burner casings are in service, and their performance has been excellent.

For protection of rotating parts where close dimensional tolerances must be maintained, cadmium plating can be successfully employed provided maximum operating temperatures are below the melting point of cadmium. The problem of protection of similar parts operating at temperatures above the melting point of cadmium is complicated by the fact that otherwise desirable metal plates, such as chromium and nickel, may seriously reduce the effective fatigue strength of the metal. Furthermore, it is virtually impossible to electroplate uniform thicknesses over surfaces of complicated parts. Because of relative uniformity of the deposited coating, electroless nickel plate holds considerable promise, although effects of this coating on fatigue endurance are not as yet known.

Where high resistance to corrosion, erosion, and abrasion must be main-

Among other obligations...

When an order is accepted the obligation to supply the commodity as stated in the contract is routine. But every purchaser knows that there are many other and additional services that the seller can render which serve the convenience and interests of the customers.

Along with every order accepted by the Bunting organization is also accepted the obligation to cooperate with the customer as well as to deliver the items as specified.

Ask *any* Bunting customer.

The sleeve bearing is not complex in structure; it conforms readily to design requirements; it is easily installed. Cast Bearing Bronze is the most adaptable of all sleeve bearing materials; it possesses excellent anti-friction properties. With proper film lubrication, its coefficient of friction is as low as can be obtained with any other bearing type. A successful Bunting Bronze bearing installation is readily attainable. We ask the opportunity to work with you, and to quote on your requirements.

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BRONZE BEARINGS • PRECISION BRONZE BARS • BUSHINGS

THE BUNTING BRASS & BRONZE COMPANY • TOLEDO 1, OHIO • BRANCHES IN PRINCIPAL CITIES

ENGINEERS
NOTEBOOK
EQUIPMENT
PHOTO COURTESY AMERICAN MOTORS CO
Support Clamp Ideal Base for Fractional-hp Motor
A Marman Support Clamp is used as a base on the American Motors Blower for cooling electrical systems. It provides a secure, light-weight attachment that is vibration-proof and trouble-free. This clamp is achieved by simply adding a cradle or support to a standard Marman Band Clamp and thus requires no special design or production. Used for almost any motor or other attachment application, it allows mounting at all angles, quick detachment because of the patented Quick Coupler Latch and a highly compact efficient assembly.
Like other Marman Clamps and Couplings, this clamp has been standardized for easy specification and production. Its familiarity to production personnel has become a positive factor in speeding assembly.
FOR ADDITIONAL INFORMATION ON THIS PRODUCT ASK FOR ENGINEER'S NOTEBOOK #18. WRITE DEPT. E-7
MARMAN PRODUCTS CO., Inc.
11214 EXPOSITION BLVD.
WEST LOS ANGELES 64, CALIF.
SAVE COST, TIME AND WEIGHT WITH MARMAN
STANDARD CLAMPS FOR SPECIAL APPLICATIONS

tained in parts which may operate at temperatures up to 1000 F, use of ferritic stainless steels seems mandatory. Such parts include axial-flow compressor blades, bolts, shafts, and turbine discs. For these applications, it appears that, in addition to the creep problem, consideration must be given to selecting the stainless grade least subject to stress-erosion cracking.

High-Temperature Alloy Developments

Since burner liners, transition ducts, nozzle guide vanes, turbine blades, turbine discs, and exhaust tail cones of turbine engines must operate at high temperatures, refractory alloys must be specified.

Burner liners, transition ducts, and parts of exhaust tail cones in a turbine engine are subjected to gas temperatures ranging from 1200 F to as high as 1800 F. Thermal stresses developed from high thermal gradients tend to produce buckling and eventual cracking. Materials which in sheet form have enjoyed the widest use for these parts are two nickel-base alloys, one of which is covered by AMS 5540. Except for their somewhat lower thermal expansion coefficients, important properties of these two alloys are comparable to those of AMS 5521 (Type 310) austenitic steel, which has also been used for these applications. Since low thermal expansion is important in minimizing thermal stresses, any new alloy developed for these applications should have at least as low expansion coefficient as have these nickel-base alloys in order to replace them on an equal performance basis.

Turbine nozzle guide vanes are subjected to very severe temperature gradients. Since turbine performance is adversely affected if nozzle throat area changes during operation, only alloys which have high creep strength at temperatures of 1600 F or higher can be considered. Since nozzle vane cross-sections are airfoils, it is desirable to make them hollow and of uniform wall thickness so that thermal stresses will be minimized. Because of their shapes, hollow nozzle guide vanes are very difficult to fabricate from high-strength heat-resistant alloys. Therefore, precision investment castings are universally used, and cobalt-base alloys are specified. Much development work has been done in attempts to produce a reduced-cobalt-content alloy having properties adequate for these applications. The presently used alloy, AMS 5385, and the three most promising substitute alloys we have seen to date are outlined in Table 3; nominal carbon

NORGE ENGINEERS SAY...

STRESSPROOF® WORKS

WHERE OTHER STEELS FAIL

STRESSPROOF was selected for this transmission pinion gear for the Norge washing machine—made by NORGE Division of Borg-Warner Corporation.

● This washing machine pinion must run for years without appreciable wear. After extensive field tests, Norge engineers found that STRESSPROOF works where other steels fail. Even heat-treated alloy, at double the cost per part, does not equal STRESSPROOF.

Then too, STRESSPROOF is used as machined. No heat treating means no distortion, with the consequent noisy operation of the washing machine. The pinions made of STRESSPROOF are clean and free of scale and require no clean-up work. They are ready for assembly as they come off the machines.

STRESSPROOF makes a better part at lower cost.

Wear resistance is only one of the four in-the-bar qualities that makes STRESSPROOF the choice for thousands of parts. *High strength*, double that of ordinary cold-finished shafting; *Machinability*, fully 50% better than heat-treated alloys of the same strength; and *Minimum warpage* in machining—are three other attributes of this unique steel.

SEND FOR Free Engineering Bulletin "New Economies in the Use of Steel Bars."

La Salle STEEL CO.

. . . the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Bars in America.

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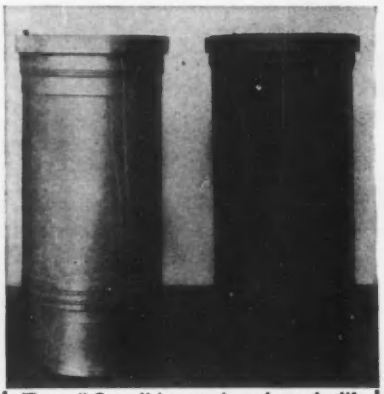
AMERICAN CHEMICAL PAINT COMPANY
AMBLER ACP PENNA.

Technical Service Data Sheet
Subject: PROTECTING FRICTION SURFACES WITH THERMOIL GRANODINE®

INTRODUCTION

Fabricators and product designers, particularly in the automotive field, are aware that even highly polished surfaces under friction weld, gall and score. One of the most inexpensive and practical methods of preventing this is to coat the metal to prevent metal-to-metal contact. With cast iron or steel, the "Thermoil-Granodine" manganese-iron phosphate coating provides a wear-resistant layer of unusual effectiveness.



Thermoil-Granodizing greatly prolongs the life of parts subject to friction. It protects the surface of products like the diesel engine liners shown above and the many moving parts of automobiles and other machines. "Thermoil-Granodine" with its remarkable lubricating properties is particularly valuable in these and similar applications because of its ability to retain oil and maintain lubrication under high pressures and high velocities. This ACP wear-proofing chemical not only permits rapid break-in without scoring, scuffing and welding but also reduces subsequent wear on friction parts.

"THERMOIL-GRANODINE" PROTECTS RUBBING PARTS

Thermoil-Granodizing removes "fuzz" from ferrous metal friction surfaces and produces a coating of non-metallic, water-insoluble manganese-iron phosphate crystals which soak up and hold oil as bare untreated metal cannot do. The oiled crystalline "Thermoil-Granodine" coating on piston rings, pistons, cylinders, cylinder liners, cranks, cam-shafts, gears, tappets, valves, spiders and other rubbing parts, allows safe break-in operation, eliminates metal-to-metal contact, maintains lubrication and reduces the danger of scuffing, scoring, welding, galling and tearing of the metal. The work to be protectively treated is merely Thermoil-Granodized and oiled, usually with a soluble oil.

"THERMOIL-GRANODINE" MEETS THESE SPECIFICATIONS

SPECIFICATION NUMBER	SPECIFICATION TITLE
MIL-C-16232 Type I	Coatings — phosphate; oiled, slushed, or waxed (for ferrous metal surfaces) and phosphate treating compounds.
AN-F-20 (See also U.S.A. 3-213)	Finishes, for electronic equipment.
U.S.A. 57-0-2C Type II, Class A	Finishes, protective, for iron and steel parts.
U.S.A. 51-70-1 Finish 22.02, Class A	Painting and finishing of fire control instruments; general specification for
M-364	Navy aeronautical process specification for compound phosphate rust-proofing process.

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "THERMOIL-GRANODINE" AND ON YOUR OWN METAL PROTECTION PROBLEMS.

CHEMICALS ACP PROCESSES

contents are between 0.27 and 0.45% and silicons between 0.50 and 0.75%. The three new casting alloys, which are similar to one another in composition, have been evaluated in laboratory creep and thermal-shock tests and are currently being tested in engine.

Requirements for turbine discs in current jet engines are that rims of discs shall have high load-carrying abilities up to temperature of 1200 F and that room-temperature yield strength in hub sections of discs shall be not less than 75,000 psi. Reasonable ductility must be available in all sections of discs, so that stress concentrations resulting from design configurations or metallurgical defects can be relieved without cracking. In small discs these requirements are not difficult to meet. But as discs get larger the problem of melting large ingots of heat-resisting alloys and forging them into sound turbine discs becomes increasingly difficult. Further, since most austenitic heat-resisting alloys require finish-forging at temperatures below recrystallization ranges in order to cold-work the material sufficiently to meet the high yield strength requirements, the forging problem increases greatly with increased disc size. For large turbine discs, composite disc design in which a cold-worked austenitic alloy rim is welded to a heat-treatable low-alloy steel hub is necessary.

Turbine blade requirements for a modern high-thrust turbojet engine are for a material with high load-carrying ability at temperatures of 1500 F and higher. In this country, two cobalt-base alloys have been developed which appear to meet these requirements—AMS 5765 forging alloy and AMS 5382 casting alloy.

To offset material shortages engine builders and alloy producers have carried on research to develop less critical blading alloys. Most effort is being directed to a nickel-base precipitation-hardening alloy.

Aluminum Welding

Abstracted from Good Aluminum Welding Starts with the Engineer by R. M. Curran, *General Electric Review*, May 1952.

THERE ARE VERY FEW MACHINES or parts manufactured that don't involve welding processes. The design engineer can help his organization avoid trouble by careful specification of materials to be used. This is especially true of aluminum alloys.

Welds made in the aluminum alloys by any of the common welding processes are subject to hot cracking at

THE Right ANSWER TO MANY DESIGN PROBLEMS

DOERR MOTORS

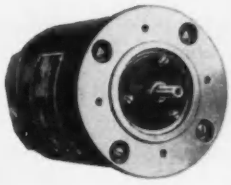
A versatile line of high quality, precision made motors in ratings from 1/30 to 5 horsepower, used by leading equipment manufacturers on a growing list of applications.

The large number of special types now in production permits the adaptation of present castings, windings and mountings to meet new design problems at a minimum of expense.

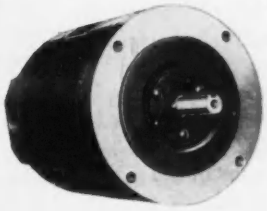
NEMA

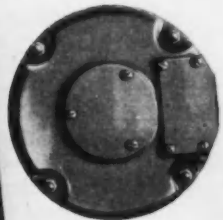
Standardized Type C Face Mountings

42 Frame

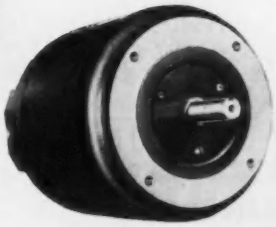


56 Frame





66 Frame



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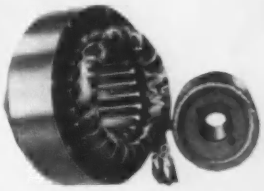

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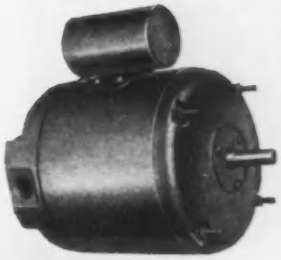

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elevated temperatures near the melting point. The tendency of these metals to crack in this manner varies greatly from alloy to alloy.

Pure aluminum has a narrow melting range whereas the alloys generally have a wider melting range. Best welding results are obtained by using alloys with narrower melting ranges.

In welding, the material in the area adjacent to the weld is subjected to both high temperatures and shrinkage stresses. These conditions tend to disrupt the lower melting (and consequently weaker) material which makes up the boundaries of the grains. The lower the melting point of the grain-boundary material and the greater the difference between the melting points of the grain-boundary material and the grain matrix, the greater the tendency toward this type of cracking.

The melting ranges of several of the more common aluminum alloys, and hence their tendency toward cracking when welded, is given in Table I.

Various Welding Processes

In brazing and in the arc- and gas-welding processes, the lower limit of the melting range must also be considered. It is not practical, for example, to braze a material which has a melting temperature lower than the flow temperature of the brazing alloy. This prevents the use of brazing on alloys whose lower melting point is below 1080 F (582 C).

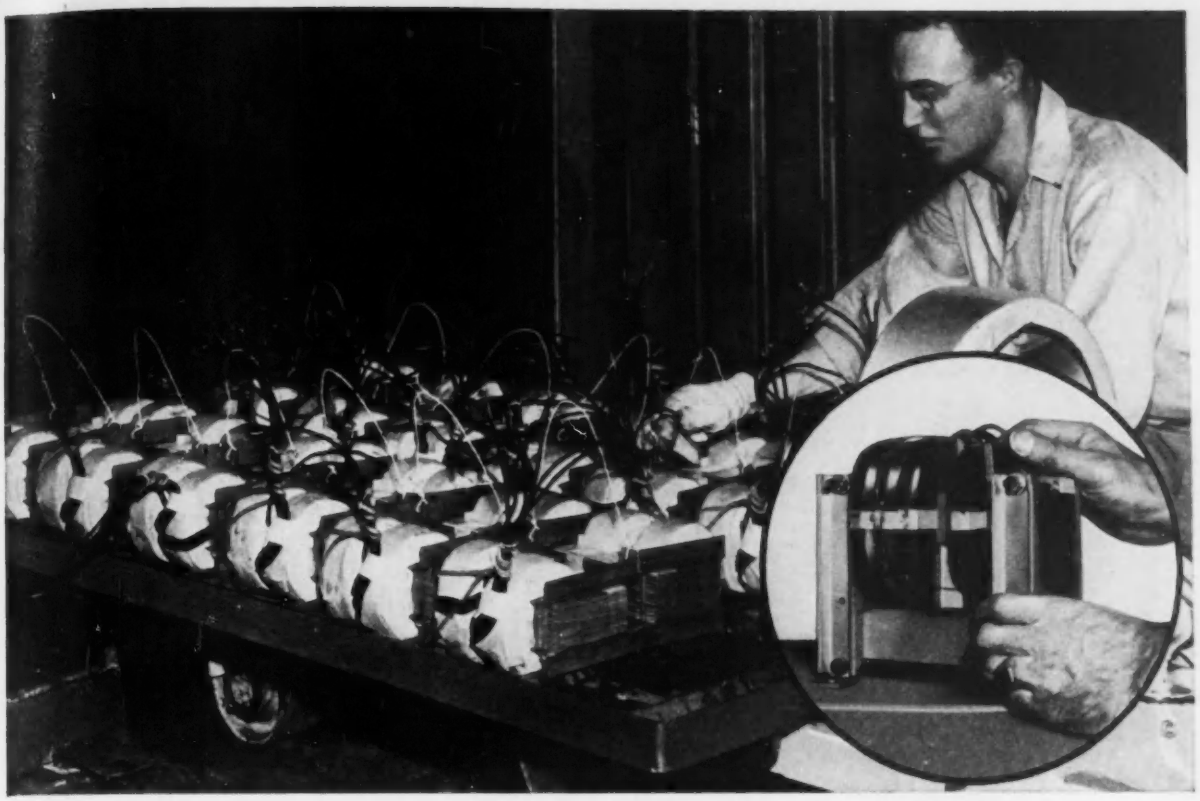
Essentially, this limits the use of brazing to 2S, 4S, 52S, 53S, 61S, and 63S wrought-aluminum alloys.

Difficulties arise, however, when the solidus temperature of the base metal is lower than the solidus temperature of the filler material. In this case, as the weld cools from welding temperature, it solidifies while the adjacent base metal is still in a semi-fluid state. To prevent fusion-line cracking, the use of filler materials which have solidus temperatures higher than that of the base material should be avoided.

In resistance welding, no filler is added. Hence, many of the alloys which cannot be welded by the arc or gas processes—or brazed—may be joined by this method. The alloys which have wide melting range, such as 24S and 75S, however, are prone to crack in spot welding. Since the major stresses imposed in flash welding are compressive, neither melting range nor lower melting point cause difficulty in producing sound welds.

Yield Strength

Since most design values are based on yield strength rather than on tensile strength, the yield strength of welded joints should be considered. Yield



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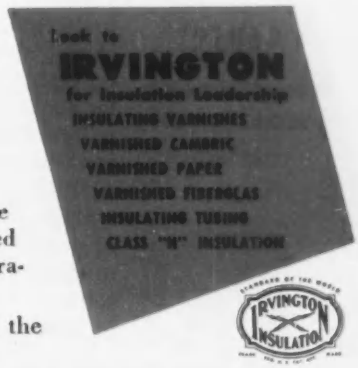

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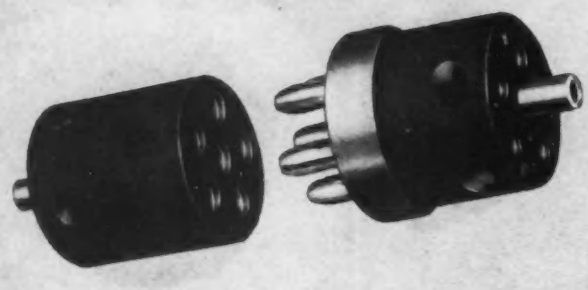

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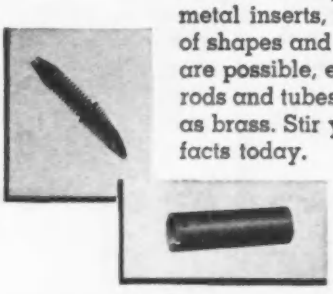

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Table I—Melting Ranges of Some Common Aluminum Alloys

Alloy	Melting Temp (degrees F)	Melting Range (degrees F)
Cast Alloys		
13	1,055 to 1,090	35
43	1,055 to 1,155	100
85	970 to 1,155	185
108	960 to 1,170	210
112	950 to 1,150	200
113	950 to 1,150	200
122	920 to 1,155	235
132	970 to 1,030	60
138	990 to 1,170	180
142	960 to 1,190	230
195	965 to 1,180	215
212	960 to 1,160	200
214	1,075 to 1,185	110
218	990 to 1,140	150
220	840 to 1,150	310
319	950 to 1,120	170
355	1,000 to 1,160	160
356	1,055 to 1,145	90
360	1,035 to 1,105	70
380	970 to 1,090	120
750	445 to 1,200	755
40E	1,060 to 1,140	80
A612	1,105 to 1,195	90
C612	1,120 to 1,190	70
Wrought Alloys		
2S	1,190 to 1,214	25
3S	1,190 to 1,210	20
4S	1,165 to 1,205	40
11S	995 to 1,190	195
14S	950 to 1,180	230
17S	955 to 1,185	230
18S	945 to 1,180	235
24S	935 to 1,180	245
25S	970 to 1,185	215
32S	990 to 1,060	70
A515	1,025 to 1,200	175
52S	1,100 to 1,200	100
53S	1,075 to 1,205	130
56S	1,055 to 1,180	125
61S	1,085 to 1,205	125
63S	1,140 to 1,205	65
75S	890 to 1,180	290
Filler Metals		
43S	1,075 to 1,165	95
711S	1,065 to 1,155	90
713S	1,070 to 1,135	65
716S	970 to 1,085	115
718	1,070 to 1,080	10

strength of homogeneous materials is usually determined by placing an extensometer on a 2-inch gage length (arbitrarily selected as a standard) and obtaining data so that the stress-strain curve may be plotted.

In a uniform material, the results may be interpreted to indicate that, when the material is stressed to the yield point, a permanent elongation of 2 mils will occur in each inch of length. In other words, in 1000 inches the permanent "set" due to the stress would be 2 inches.

In a welded joint, however, elongation does not take place uniformly over the entire gage length; it is confined

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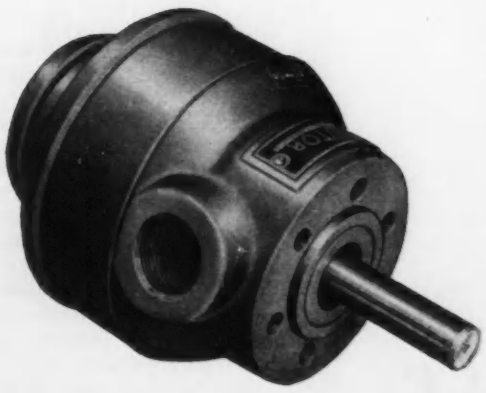

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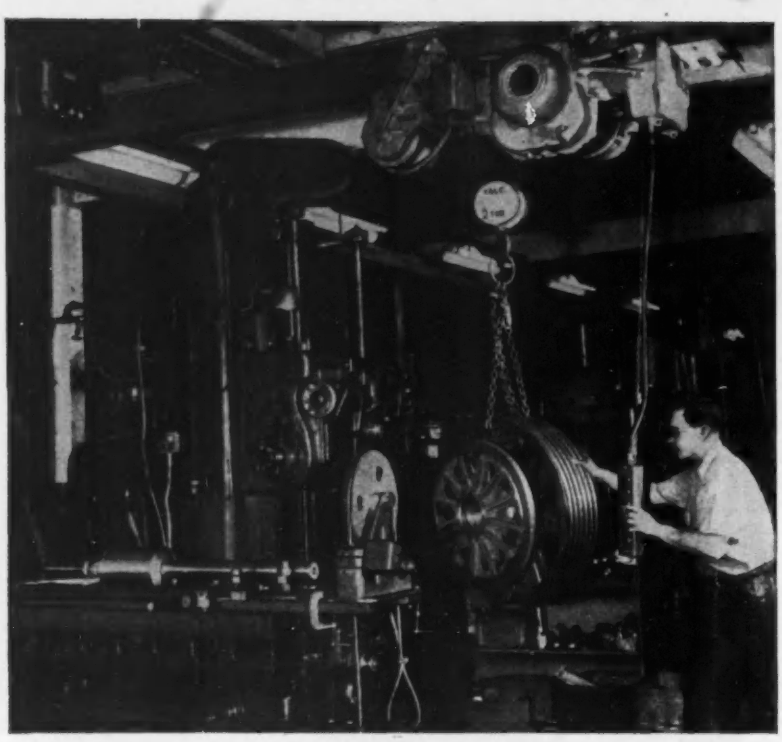

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Trolley motor is a Star-Kimble Brakemotor that spots the load accurately — no need for time-consuming inching. Adjustable braking torque brings the load to quick, smooth stops.

This is typical of the many ways in which Star-Kimble engineering skill has benefited the designers and users of all sorts of motor-driven equipment.

For information on design and service features of Star-Kimble Squirrel-Cage Motors, write for Bulletin B-211; for Brakemotors, Bulletin B-501-A.

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to a narrow band which may represent as little as one-sixteenth of the total gage. If yield strength is measured in the same manner as for uniform materials, the locally yielding area must elongate approximately 16 times as much.

Ductiltiy

When we consider the ductility of welded joints as measured by the percent elongation in 2 inches, the situation is much the same as for yield strength. If the heat-affected zone, representing one-sixteenth of the total gage length, should elongate 50 percent, the reported elongation in 2 inches would be 50/16, or 3 percent. It should be realized that this low value arises from the heterogeneity of the section tested; it does not indicate brittleness.

The low elongation values encountered in welding aluminum present a serious problem when a structure is subjected to tensile impact loading; for the energy absorbed by such a structure under that type of load is proportional to the product of the volume of material deformed and the stress necessary to cause deformation.

In high-strength aluminum alloys, the total volume of metal deformed in tensile impact loading is small. The reason for this is that the yield strength of the heat-affected zone or weld metal usually is less than that of the parent metal, and the elongation is confined to the narrow area in the vicinity of the weld.

In tensile impact loading, the use of alloys in the annealed condition will, usually result in higher energy absorption than will the use of hard-tempered materials. And the reason is that the lower yield strength is more than compensated for by the great increase in the volume of metal deformed, which results from the uniform yield strengths of weld and base metal.

The modulus of elasticity is essentially the same for all aluminum alloys and is not affected by heat treatment or the softening effects of welding.

A suggested procedure to follow when selecting aluminum alloys for welded construction is:

1. On the basis of joint design, material thickness, and volume of production, select the welding process which is most applicable.
2. Select the alloys which are recommended for fabrication by the process selected.
3. Determine the approximate weld properties from publications of the aluminum companies or the ASM.
4. Be sure your alloy is available in the shape you need.

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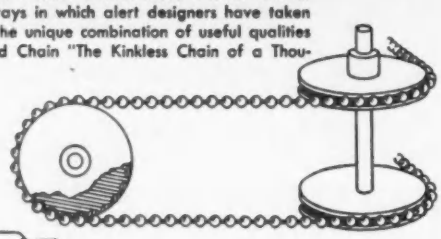

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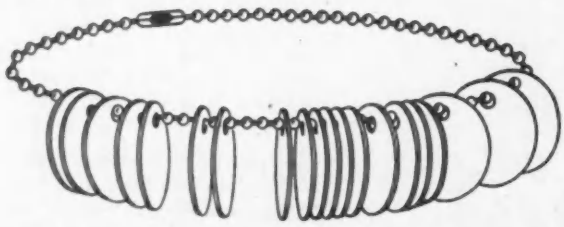

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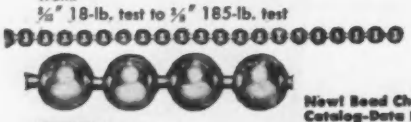

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OUR READERS SAY

Design Charts for Large Compression Springs

To the Editor:

In the article "Design Charts for Large Compression Springs," on pages 203, 205, and 207, of the February 1952 issue of PRODUCT ENGINEERING, I was astonished that the Wahl stress factor had been neglected by the author. After establishing a conservative value of permissible stress equal to 100,000 psi, the author did not explain for which spring constructions the above stress value could be safely used. Utilizing the data of the numerical example on page 203, I am intending to set forth how faulty, and even dangerous the practical application of the charts in question will be.

As a true basis for spring calculation, a curve of ultimate torsional strength T of standard spring steel is enclosed. From this curve T = 163,000 psi for a 1¼ in. bar quenched. Corresponding yield strength is 130,000 psi. Maximum torsional stress, generally corresponding to solid stress of the spring, is

$$S = 8P(D - d)\ K/\pi d^3$$

In the formula: P = maximum spring load, lb; D = outside diameter of the spring in inches; d = diameter of spring wire or bar in inches; K = stress correction factor equal to

$$\frac{C - 1.25}{C - 2} + \frac{0.615}{C - 1}$$

in which C = D/d.

Selecting D = 6¼ in., d = 1¼ in., C = 5, K = 1.40, P = 15,330 lb, we obtain S = 140,000. This value is higher than the yield strength of the material causing residuary deformations in the spring. With a 55 percent lower working load, established by the author, equal to 8,400 lb, the corresponding stress will be

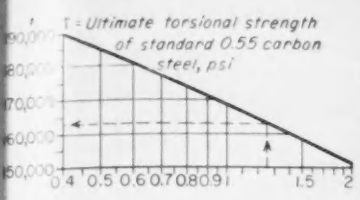
$$140{,}000 \times 8{,}400/15{,}330 = 76{,}600 \text{ psi},$$

and the factor of structural safety will be

$$T = 163{,}000/76{,}600 = 2.14$$

According to Board of Trade Rules, however, a safety factor of 3 is permissible for shock absorbers, and a safety factor of 5 is permissible for safety valve springs.

A 55 percent difference of loads is



too high. In practice, a solid load on the spring is only 10 to 15 percent higher than the working load. Otherwise we obtain a poorly designed spring.

Utilizing the Spring Design Charts for calculating a compression spring on the basis of the spring's outside diameter and the specified maximum working load is difficult, as it requires several corrections on stress concentration; and the actual ultimate torsional strength of the material, as well as a consideration of a reasonable value of safety factor, corresponding to the nature of duty for which the spring is designed.

—VICTOR TATARINOV
Czechoslovakia

May Issue Well Received

To the Editor:

I feel that PRODUCT ENGINEERING has done an outstanding job in presenting "Engineering Your Company's Future" and I am pleased that the Mechanical Engineering Dept. of N. Y. U. made some contribution toward it. I predict you will have a large demand for reprints of this section.

It was a great pleasure to work with you on the Conference at New York University and if you should ever plan to have a repeat performance in this area, we should be very happy to be asked to cooperate again.

—A. H. CHURCH, *Chairman*
Mechanical Engrg. Dept.
New York University

To the Editor:

You and the people at PRODUCT ENGINEERING who planned and wrote the supplement for the May issue deserve a great deal of credit for the excellent way in which you put together the Engineering Department study.

This insert is worthy of close study by engineering topside folk and will undoubtedly provoke a great deal of analysis. The people here who should see PE are already reading copies. As you may know, the company is ordering reprints.

The section was even more ambitious in size and scope than I had expected. I'm naturally glad that you

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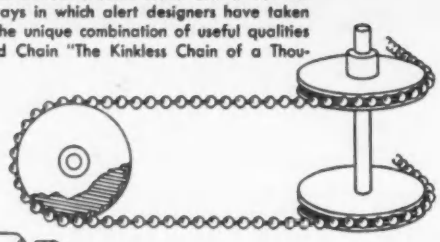

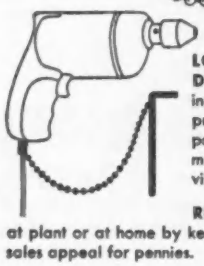

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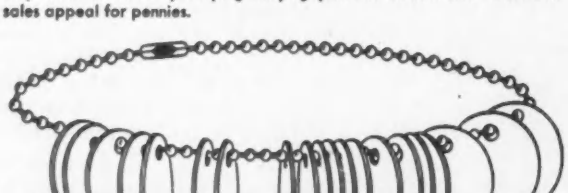

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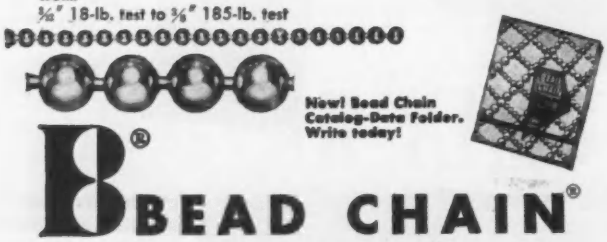

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To the Editor:

In the article "Design Charts for Large Compression Springs," on pages 203, 205, and 207, of the February 1952 issue of PRODUCT ENGINEERING, I was astonished that the Wahl stress factor had been neglected by the author. After establishing a conservative value of permissible stress equal to 100,000 psi, the author did not explain for which spring constructions the above stress value could be safely used. Utilizing the data of the numerical example on page 203, I am intending to set forth how faulty, and even dangerous the practical application of the charts in question will be.

As a true basis for spring calculation, a curve of ultimate torsional strength T of standard spring steel is enclosed. From this curve T = 163,000 psi for a 1¼ in. bar quenched. Corresponding yield strength is 130,000 psi. Maximum torsional stress, generally corresponding to solid stress of the spring, is

$$S = 8P\,(D - d)\;K/\pi d^3$$

In the formula: P = maximum spring load, lb; D = outside diameter of the spring in inches; d = diameter of spring wire or bar in inches; K = stress correction factor equal to

$$\frac{C - 1.25}{C - 2} + \frac{0.615}{C - 1}$$

in which C = D/d.

Selecting D = 6¼ in., d = 1¼ in., C = 5, K = 1.40, P = 15,330 lb, we obtain S = 140,000. This value is higher than the yield strength of the material causing residuary deformations in the spring. With a 55 percent lower working load, established by the author, equal to 8,400 lb, the corresponding stress will be

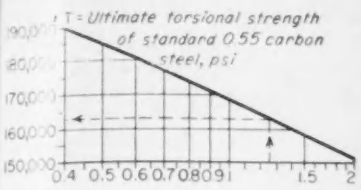
$$140{,}000 \times 8{,}400/15{,}330 = 76{,}600 \text{ psi},$$

and the factor of structural safety will be

$$T = 163{,}000/76{,}600 = 2.14$$

According to Board of Trade Rules, however, a safety factor of 3 is permissible for shock absorbers, and a safety factor of 5 is permissible for safety valve springs.

A 55 percent difference of loads is



too high. In practice, a solid load on the spring is only 10 to 15 percent higher than the working load. Otherwise we obtain a poorly designed spring.

Utilizing the Spring Design Charts for calculating a compression spring on the basis of the spring's outside diameter and the specified maximum working load is difficult, as it requires several corrections on stress concentration; and the actual ultimate torsional strength of the material, as well as a consideration of a reasonable value of safety factor, corresponding to the nature of duty for which the spring is designed.

—VICTOR TATARINOV
Czechoslovakia

May Issue Well Received

To the Editor:

I feel that PRODUCT ENGINEERING has done an outstanding job in presenting "Engineering Your Company's Future" and I am pleased that the Mechanical Engineering Dept. of N. Y. U. made some contribution toward it. I predict you will have a large demand for reprints of this section.

It was a great pleasure to work with you on the Conference at New York University and if you should ever plan to have a repeat performance in this area, we should be very happy to be asked to cooperate again.

—A. H. CHURCH, *Chairman*
Mechanical Engrg. Dept.
New York University

To the Editor:

You and the people at PRODUCT ENGINEERING who planned and wrote the supplement for the May issue deserve a great deal of credit for the excellent way in which you put together the Engineering Department study.

This insert is worthy of close study by engineering topside folk and will undoubtedly provoke a great deal of analysis. The people here who should see PE are already reading copies. As you may know, the company is ordering reprints.

The section was even more ambitious in size and scope than I had expected. I'm naturally glad that you

Savings UP TO 50% IN FINISHING TIME
with New ARCO HOT SPRAY

Write Dept. 11 for this new booklet that tells the story of Hot Spray's "DOUBLE DIVIDEND"

AS FEW AS 2 COATS can do the work of 4...with Arco's Control-Temp* system of product finishing...the only hot spray system where materials and equipment were researched and engineered together to save you up to 50% in time and labor. Arco's Control-Temp System sprays higher solids, gives greater coverage with fewer coats...pays an extra dividend in "Quality that never varies." Write for the booklet today.

*Patent applied for

Paints, Lacquers, Varnishes, Enamels, Protective Coatings
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ARCO PAINTS
Quality... SINCE 1881

TESTED FIRST TO LAST!

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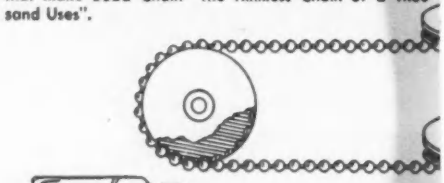
A subsidiary of American-Marietta Company

IMAGINATION plus

BEAD

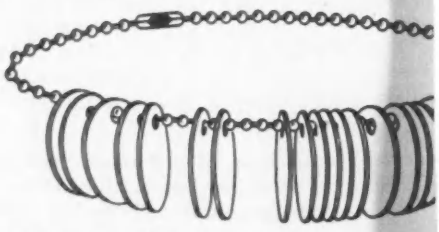
means BETTER PR

WHAT OTHERS HAVE DONE: Here are a few of the scores of ways in which alert designers have taken advantage of the unique combination of useful qualities that make Bead Chain "The Kinkless Chain of a Thousand Uses".



LOW-COST, THREE DIMENSION DRIVE Made possible by non-kink ing action of each bead. Slippa prevented as each bead fits in pocket. Bead Chain drives have many products such as business vision tuners, venetian blinds, etc.

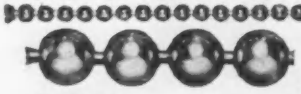
RETAINER FOR STRAYING PA at plant or at home by keeping straying parts at hand. sales appeal for pennies.



CONNECTOR FOR SAMPLES For fabrics, paint, plastic non-kinking, attractive, strong.

It will pay you to think how Bead Chain could help impr
As the world's largest manufacturer of Bead Chain, we how" acquired in applying Bead Chain to meet the requ sands of uses. Call on us.

Bead Chain is available in many metals and finishes, from:
⅛" 18-lb. test to ⅜" 185-lb. test



New! Bead Chain Catalog-Data Folder. Write today!

BEAD CHA...

The Bead Chain Manufacturing Co.,
92 Mt. Grove Street, Bridgeport, Connecticut.

OUR READERS SAY

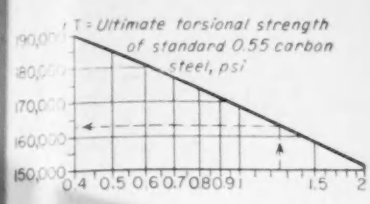
PA

MIS.

safety factor of 5 is permissible for safety valve springs.

A 55 percent difference of loads is

Our Readers Say.....continued



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*Patent applied for

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TESTED FIRST TO LAST!

THE ARCO COMPANY, CLEVELAND 27, OHIO
ARCO COMPANY OF CALIF. LTD., LOS ANGELES 1, CALIF.
A subsidiary of American-Marietta Company

AGES

SSING

The section was even more ambitious in size and scope than I had expected. I'm naturally glad that you

COOLIDGE
BALLS
CHROME ALLOY
STAINLESS STEEL

•

Finest:
ELECTRIC FURNACE STEEL
HEAT TREATMENT
LAPPED FINISHES

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THESE FACTORS COMBINE TO MAKE THE FINEST STEEL BALLS OBTAINABLE BECAUSE THEY CONTRIBUTE TO CLOSER SURFACE UNIFORMITY—BETTER STRAIN DISTRIBUTION—HIGHER LOAD CARRYING CAPACITY—LONGER LIFE

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Used in:
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FARM AND INDUSTRIAL EQUIPMENT
MACHINE TOOL • OIL WELL AND OTHER
IMPORTANT APPLICATIONS

•

COOLIDGE
CORPORATION
BOX 488 • MIDDLETOWN, OHIO

were included in the section, and happy that you found some part of our operation here worthy of note.

—FRANK BUCHNER
Curtiss-Wright Corp.
Wright Aeronautical Div.

To the Editor:

I have just received my May issue of PRODUCT ENGINEERING, and am writing to you to express my sincere appreciation and praise on the most needed topic of the day.

"Engineering Your Company's Future" is a masterpiece that should wake up all intelligent men who are directly or indirectly responsible for the organization and operation of the engineering departments of large or small companies.

For years I have been looking for such a study as you have presented in this issue, and at last it's here. Hats off to PRODUCT ENGINEERING! Let's have more timely articles like this in the coming issues. —H. R. PIERCE
Rahway, N. J.

Micro Switch

To the Editor:

We have read with interest the article entitled "Overload Release for Torque-Arm Speed Reducer" on page 234 of your fine magazine for April, 1952. We note that in it you have, no doubt inadvertently, used our trademark "Micro Switch" incorrectly.

We call your attention to the fact that "Micro Switch" is our trademark used to distinguish switches and other products of our manufacture from those of others. It can properly be used only to designate such products.

In order to protect our trademark rights, we must object to any improper use of this mark and we would, therefore, appreciate it if in the future you would indicate its trademark significance by at least capitalizing "M" and "S".

We thank you for your cooperation.

—A. R. KOCH
Micro Switch Inc.

New Alloy's Properties

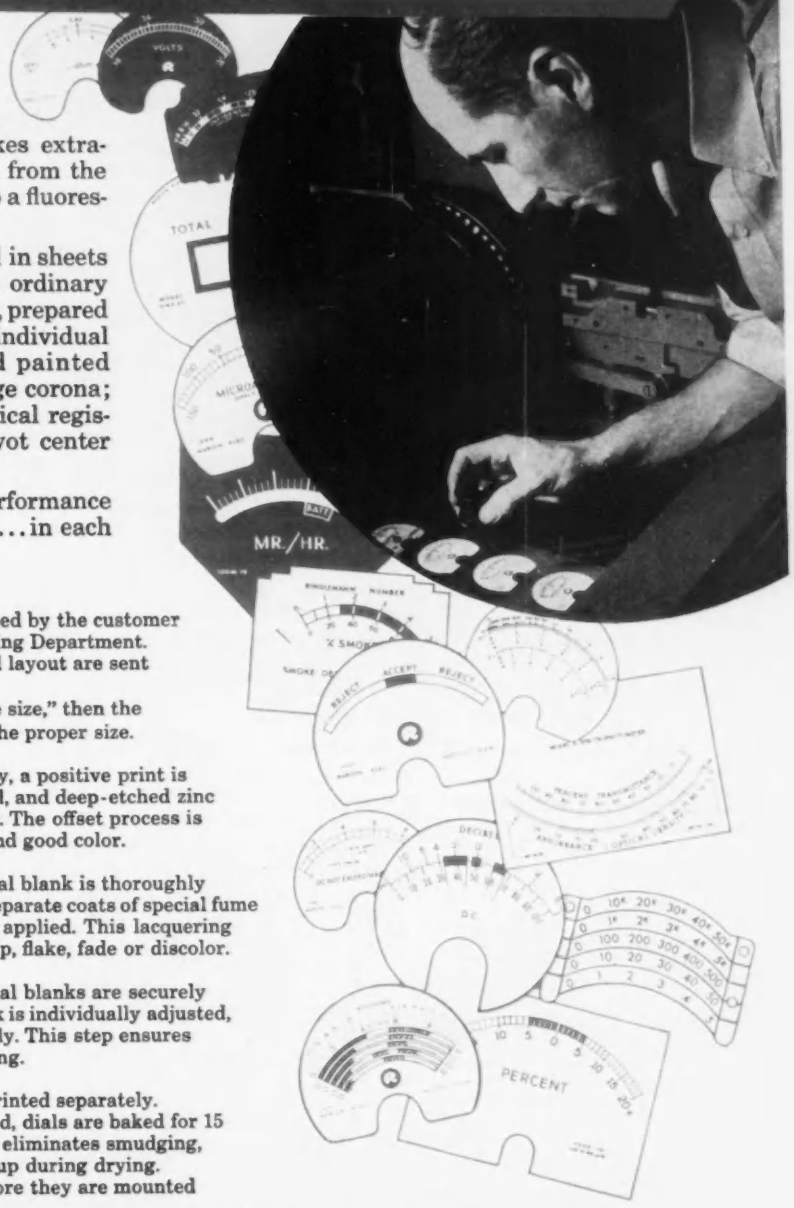
To the Editor:

We have read with alarm the item "New Alloy with Unusual Properties" which appeared on page 224 in the April issue of PRODUCT ENGINEERING.

While the item is quite indefinite as to the precise composition and mechanical properties of Chemalloy, and little data is provided on the methods

marion methods

die-cut, process and print each dial individually



Because the accuracy of an indicating instrument is completely dependent upon the accuracy of its dial, Marion takes extraordinary care with each dial . . . from the simplest black and white type to a fluorescent type of seven colors.

Marion dials are never printed in sheets and then stamped out, as are ordinary dials. Each Marion dial is die-cut, prepared and printed *separately*. This individual handling guarantees finished painted edges, which reduces high voltage corona; it also assures accurate mechanical registration of the dial with the pivot center of the instrument.

Precision and dependable performance are built into every Marion dial . . . in each step of manufacture.

Preliminary Operations . . . Dial data furnished by the customer is carefully checked by Marion's Engineering Department. After Engineering OK, data and suggested layout are sent to the Art Department.

The dial scale is drawn 4 to 6 times "life size," then the drawing is photographed and reduced to the proper size.

Preparation of Plates . . . After photography, a positive print is made. Color separations are made by hand, and deep-etched zinc plates for offset lithography are produced. The offset process is used to assure sharp printing definition and good color.

Preparation of Dial Blank . . . Each metal dial blank is thoroughly rinsed and vapor de-greased. Then, three separate coats of special fume and age-proof eggshell-white lacquer are applied. This lacquering technique gives a surface that will not chip, flake, fade or discolor.

Registering . . . After careful inspection, dial blanks are securely mounted on the printing press. Each blank is individually adjusted, and the printing plate is positioned exactly. This step ensures perfect registration for multi-color printing.

Printing and Drying . . . Each dial is then printed separately. After special inks of each color are applied, dials are baked for 15 to 20 minutes to set the ink. This process eliminates smudging, and minimizes the amount of lint picked up during drying. Dials are thoroughly inspected again before they are mounted on Marion instruments.

Other Marion Methods. Marion's method of assuring the top accuracy and service of each dial by individual handling is only one of a number of methods which Marion is presenting in the hope that some of them will help you as they have helped us. We will be pleased to send more information if desired.

MARION ELECTRICAL INSTRUMENT CO., 428 CANAL ST., MANCHESTER, N. H.

marion meters

MANUFACTURERS OF MARION Ruggedized PANEL METERS

LUSTER-ON®

makes the difference

At less than 1/5¢ per square foot you can have brilliant finishes like this with Luster-on Utility bright dip for zinc. It's easy to apply and control and there's plenty available — no shortages. Every day former users of nickel and cadmium are converting to this passivating bright dip.

CHECK LIST

Do you produce parts like those listed below? Then you can obtain corrosion-resistant, brilliant finishes at lowest costs with Luster-on Utility 15 or 25.

- ✓Cabinet Hardware
- ✓Small Tools (wrenches, etc.)
- ✓Auto Body Parts
- ✓Bathroom Hardware
- ✓Aircraft Metal Parts
- ✓Wire Goods
- ✓Refrigerator Shelves
- ✓Radio Speakers, Chassis, Shields
- ✓Television Parts
- ✓Electrical Parts
- ✓Air Conditioning Fans, Guards, etc.
- ✓Bolts, Nuts, Washers, etc.
- ✓Builders' Hardware
- ✓Outdoor Metal Articles (fences, trailers, etc.)

Also

Protective Finishes
Khaki Drab Luster-on

With 300 hours of salt spray resistance Luster-on Khaki Drab far exceeds U. S. Government Specifications of 96 to 100 hours. This chromate type conversion coating has been developed primarily for electro-deposited zinc plate. It is also ideal as a paint bonding treatment for later organic finishes.

SEND SAMPLES

Send us samples of your parts. Let us zinc-plate and LUSTER-ON treat them for you — at No Charge. This will show you how you can dress up and protect your product simply and inexpensively with Luster-on.

THE Chemical CORPORATION
59 Waltham Ave., Springfield 9, Mass.

of fabrication and fields of use. it is stated that the new alloy "is said to have unusually efficient properties for pressure die casting." As anyone familiar with die castings is well aware, a zinc base alloy of even approximately the composition given in the item should never be used for die casting.

As the result of exhaustive tests inaugurated in 1927 under the auspices of the American Society for Testing Materials, it has been proved conclusively that zinc die castings should not contain lead in excess of 0.007 percent, cadmium in excess of 0.005 percent, and not more than 0.005 percent tin. Furthermore, the minmum allowable aluminum should be 3.5 percent and the copper should not exceed 3.5 percent. If the above limits are exceeded, intergranular or a subsurface network type of corrosion will result with changes in strength and properties.

All competent die casters are familiar with the above information and will not tolerate the use of any zinc alloys which do not conform to the ASTM Specification—B86 covering zinc base die castings. —C. R. R.

Product Engineering Used in India

To the Editor:

I wish to acknowledge with grateful thanks the receipt of tear sheets of the article "Stress in Rotating Disks of Nonuniform Thickness" in response to my request to Prof. Gawain. I would like to add that we in this part of the globe consider PRODUCT ENGINEERING one of the finest magazines of its kind.

With kindest compliments,

A. K. CHAUDHURI, *M. A. Sc.*
Dept. of Mech. Engineering
University of Roorkee
Roorkee, U. P., India

No Shortage of Engineers

To the Editor:

This letter is to tell you how very much I enjoyed your editorial in the April 1952 issue of PRODUCT ENGINEERING. It is the best written, clearest and timeliest of any that have appeared in print.

"If supply and demand is not to be allowed to operate in one direction, it should not be allowed to operate in the opposite direction." It has certainly been allowed to operate when the demand for engineers was prac-

PROBLEM: Get a compact pump that provides both vacuum and pressure in a gas-air system required for operation of Leeds & Northrup Microcarb Atmosphere Control applied to the Homocarb Furnace equipment.

SOLUTION: One Gast Integral Oil-less Air Pump does double duty. It provides low vacuum to draw a continuous 2 cu. ft. per hr. sample of furnace gas over the atmosphere detector. At the same time the pump maintains a mixture of furnace atmosphere and air at 5 to 10 pounds pressure in the system on the discharge side of pump.

RESULT: Positive displacement pump provides absolutely oil-free air, and eliminates worries about lubrication. Rotary design runs quiet and cool.

SUCH AN EXAMPLE as this may contain a clue to solving a similar or even totally different problem on your desk. You might be surprised at the innumerable applications for air pumps and air motors in the lower capacity ranges. Write today describing your original equipment problem. We'll send full details. "Air may be your Answer."

Gast Application Ideas Booklet — showing 26 design problems solved — sent upon request.

see our CATALOG in SWEET'S FILE

Original Equipment Manufacturers for Over 25 Years

GAST ROTARY
AIR MOTORS (TO THREE H.P.) · COMPRESSORS (TO 30 LBS.) · VACUUM PUMPS (TO 28 INCHES)
GAST MANUFACTURING CORP., 139 Hinkley St., Benton Harbor, Mich.

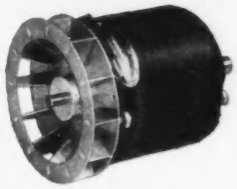
assured RELIABILITY

WITH

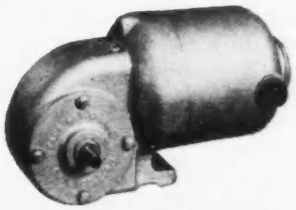
Lamb Electric

SPECIAL APPLICATION
FRACTIONAL HORSEPOWER
MOTORS

Series motor parts engineered for floor polisher; adaptable to food mixers and other household appliances.



Compactly designed capacitor-type induction motor for wire recorders, electronic tube cooling, and similar services.



Ruggedly designed motor with triple thread worm gear reduction for vending machines, advertising displays, and similar applications.

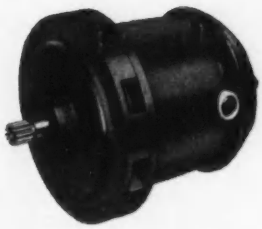
...an end result of special engineering

In the hands of users . . . the real "proving ground" of all products . . . devices powered with Lamb Electric Motors have won a reputation for long, trouble-free operation.

Motor reliability, a prime requisite for successful product operation, is assured with Lamb Electric Motors because (1) the motor is designed for the specific application, (2) it is built of quality materials to the highest manufacturing standards, (3) it embodies 37 years' experience in the small motor field.

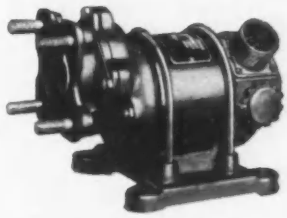
Reliability is but one of the advantages gained through the use of a specially engineered Lamb Electric Motor.

THE LAMB ELECTRIC COMPANY
KENT, OHIO
In Canada: Lamb Electric—Division of Sangamo Company Ltd.—Leaside, Ontario



Rugged construction is a major factor in the reliability of this motor widely used in the field of mechanized equipment.

A high vacuum with high volume turbine unit for commercial or industrial vacuum or blower applications.

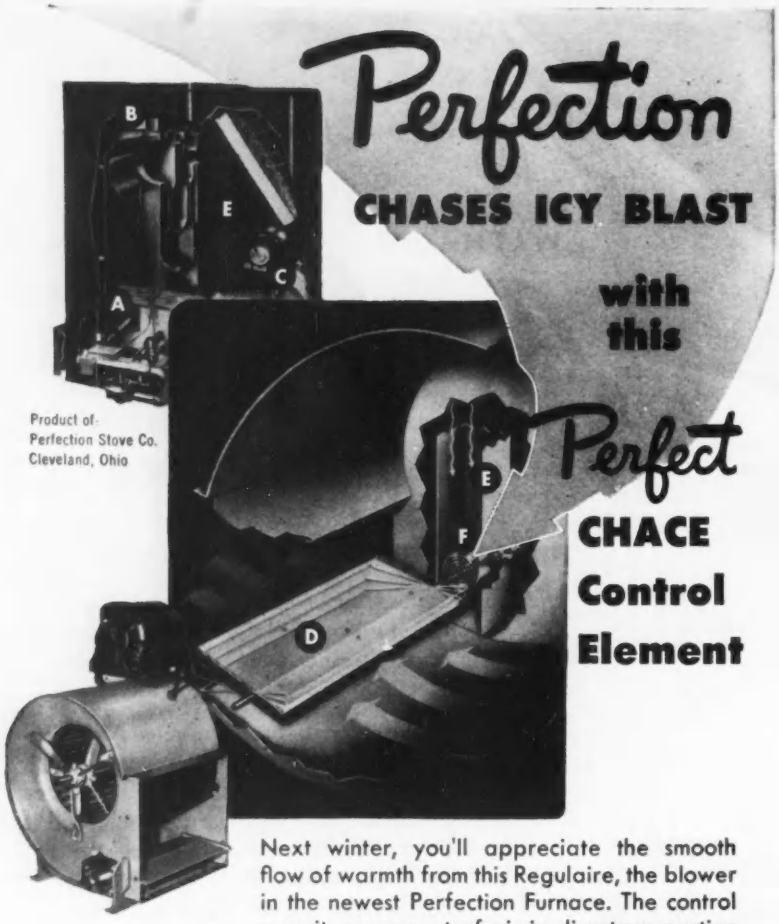


Base-mounted, explosion-proof aircraft geared fuel transfer pump motor.

THEY'RE POWERING AMERICA'S Finest PRODUCTS

Lamb Electric

SPECIAL APPLICATION
FRACTIONAL HORSEPOWER **MOTORS**



Next winter, you'll appreciate the smooth flow of warmth from this Regulaire, the blower in the newest Perfection Furnace. The control permits movement of air in direct proportion to the furnace output, eliminating cold floors, chilly drafts, noisy blower operation and other discomforts of ordinary "blow cold—blow hot" heating. Chace Thermostatic Bimetal actuates the vane which restricts the blower outlet until the temperature reaches a comfortable level.

After the thermostat is set at desired temperature, burner (A) comes on at coasting fire, then turns to high fire if the rooms are cold. When the furnace bonnet (B) becomes warm, the blower (C) begins quiet delivery of warmth with vane (D) closed. Warm air is drawn down duct (E) and warms bimetal coil (F) which gradually opens vane (D) to gently increase flow of warm air to your rooms. It is this bimetal coil's sensitivity to the slightest change in temperature—plus a 3-stage burner—that regulates the flow of warmth to your rooms and assures perfect heating comfort in any weather.

Our 29 types of thermostatic bimetal are available in strips, coils, random long lengths and welded or brazed sub-assemblies. If the actuating element for your new control device is thermostatic bimetal, Chace can furnish it completely fabricated, ready for assembly. Our engineers, recognized authorities on temperature responsive devices, are available for consultation. Write today for our new 32-page booklet, "Successful Applications of Chace Thermostatic Bimetal," containing condensed engineering data.

W. M. CHACE CO.
Thermostatic Bimetal
1607 BEARD AVE., DETROIT 9, MICH.

tically zero. Only two short years ago the majority of the magazines contained articles describing the overcrowding of the engineering profession, and how practically impossible it was to secure a salary increase, since there were plenty of applicants to take any job opening.

I am not convinced that there is a shortage of qualified engineers! Too many companies try to hire men too highly qualified for the jobs they are to fill. I've seen dozens of engineers on jobs that could have been filled by bookkeepers, typists, or plant trained personnel. This is still largely true today, because many companies hoard engineers by placing them in non-engineering jobs until such a time arises as to require their services on that "new construction job." Most of the major oil companies are guilty of this practice and are not in the market for any great number of new engineers. The Oil and Gas Journal "help wanted" section is indicative of this.

Engineering salaries have been too low in comparison to those paid organized labor. The engineer has been too much like the school teacher—an example of the profession not to get into.

I am also 100 percent against the education of engineers, etc. by the Federal Government at the expense of the taxpayer! —LESTER P. JENKINS
Tulsa, Oklahoma

Ed—You can say that again, brother.

Sources of Silicon Monoxide

To the Editor:

We noticed in "Our Readers Say" of the PRODUCT ENGINEERING, for May 1952, an inquiry concerning Silicon Monoxide.

This material may be obtained from either the National Research Corporation, Memorial Drive, Cambridge, Mass., who market Silicon Monoxide under the tradename "Silicote," or from Kemet Company, P. O. Box 6087, Cleveland 1, Ohio.

—I. P. STAPSY
Buhl Optical Company

Charactron High Speed Printer

To the Editor:

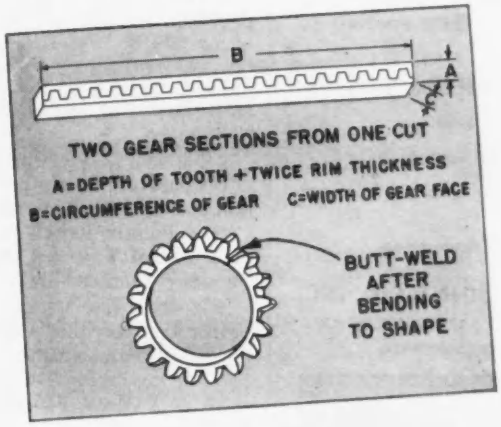
The article dealing with a development by Consolidated Vultee Aircraft of a high speed "printer," is very interesting to put it mildly.

Can you advise me whom we can con-

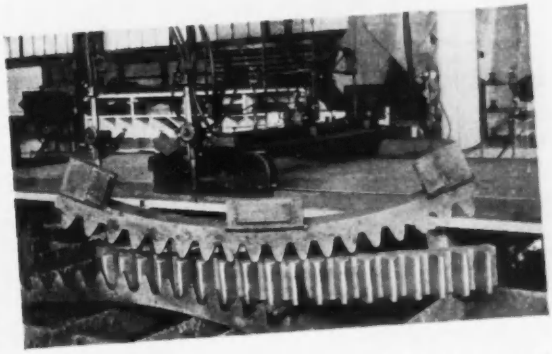
Ideas on Welded Design—For the Engineer's Notebook

DON'T OVERDESIGN

Careful consideration of allowable tolerances often results in reduced costs through elimination of overdesigned parts. Precision gears, for example, are an unwarranted expense where more economical gears that are accurate within 1/64 inch will give just as satisfactory service.


B
A
TWO GEAR SECTIONS FROM ONE CUT
A=DEPTH OF TOOTH +TWICE RIM THICKNESS
B=CIRCUMFERENCE OF GEAR C=WIDTH OF GEAR FACE
BUTT-WELD AFTER BENDING TO SHAPE

Such gears, for farm machinery, cement mixers, and similar equipment are produced by oxygen-cutting and welding as shown in the sketch. One cut makes two gear sections. There is no scrap loss. Welded circular sections require further finishing only in weld areas.



Eight steel sections like this, oxygen-cut from 5-in. thick slabs, are welded together to make 14-ft. diameter gears for pontoon cranes. Maximum tolerance is only 1/32 in., but no machining is required.

For further information about oxygen-cutting, welding and other cost reducing LINDE methods, phone or write LINDE AIR PRODUCTS COMPANY, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N.Y. Offices in Other Principal Cities. In Canada: Dominion Oxygen Company, Limited, Toronto.

More Ideas For Profit

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30 East 42nd Street, New York 17, N.Y.

Please send me my free copy of 20-page booklet, F-7811, entitled "Improved Design for Welding."

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Company.....

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The Most Economical

Made of fewer parts, each part of specially selected steel, individually hardened for a specific purpose — they last longer.

CURTIS UNIVERSAL JOINTS

Not only do they give efficient service for a longer period of time but they are easier to install, quicker to assemble and disassemble. 14 standard sizes to choose from—with either solid or bored hubs. Facilities immediately available to produce specials to specifications.

ONLY CURTIS OFFERS ALL THESE ADVANTAGES

Availability — 14 sizes always in stock.

Simplicity — fewer parts, simpler construction.

Government Tests — complete equipment for government tests in our plant.

Write today for free engineering data and price list

CURTIS UNIVERSAL JOINT CO., INC.
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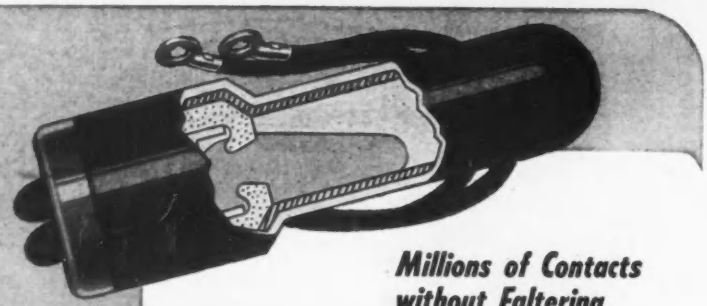
As near to you as your telephone

A MANUFACTURER OF UNIVERSAL JOINTS SINCE 1928



Millions of Contacts without Faltering

PROVED

ON ROUGH, TOUGH JOBS

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tact for more detail as to the type of forms used and other data of like nature? Where is a model in use?

Any further information you can supply will be greatly appreciated.

—J. R. HERMANN
Moore Business Forms, Inc.

Ed—Mr. J. T. McNaney of the Consolidated Vultee Aircraft Corp, San Diego, California, developed the Charactron Tube. We suggest that you contact him in regard to further information about the tube. He is working with the Haloid Company of Rochester, N. Y., in the development of the printer for use with the charactron tube.

Impregnation Information

To the Editor:

I would appreciate more information on the article "Impregnation Cuts Casting Porosity Rejects" published on page 193 of February 1952 issue of PRODUCT ENGINEERING.

We would like a suggestion on the proper thermosetting Copolymer and the manufacturer's name if possible.

—C. VAN SICKEL
Motor Wheel Corporation

Ed—Additional information may be obtained from Mr. M. Jordon Nathason, President, Western Sealant Inc., Culver City, California. Western Sealant makes the material described in this article.

ERRATA

April 1952, Page 170. *Operation and Applications of the Differential Analyzer.* Fig. 11, lower right—the equation $u = \int wdu$ should read $v = \int wdu$.

April 1952, Page 185. *Hydraulic Noise Reduction by Fluid Reconditioning.* Bottom of the third column—first equation for V should be a lower case v, the kinematic viscosity.

April 1952, Page 236. *High Voltage Mercury Thyratron Tube.* Correct address of this supplier is: Sheldon Electric Company, Inc., 76 Coit St., Irvington, N. J.

May 1952, Page 250. *Stationary or Rotating Syphon on Revolving Joint.* Manufacturer's name incorrectly spelled as Rothern Engineering Co., Inc. Should be Rotherm Engineering Co., Inc.

May 1952, Page 264. *A New Positive Mechanical Shaft Seal.* Manufacturer's name incorrectly spelled as Cartiseal Corp. Should be Cartriseal Corp.

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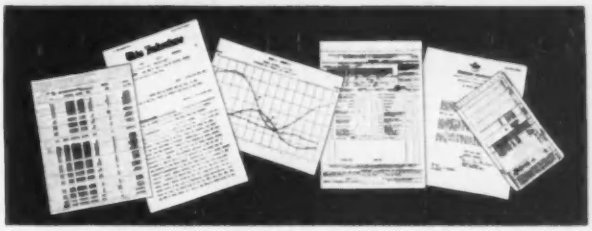

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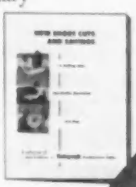

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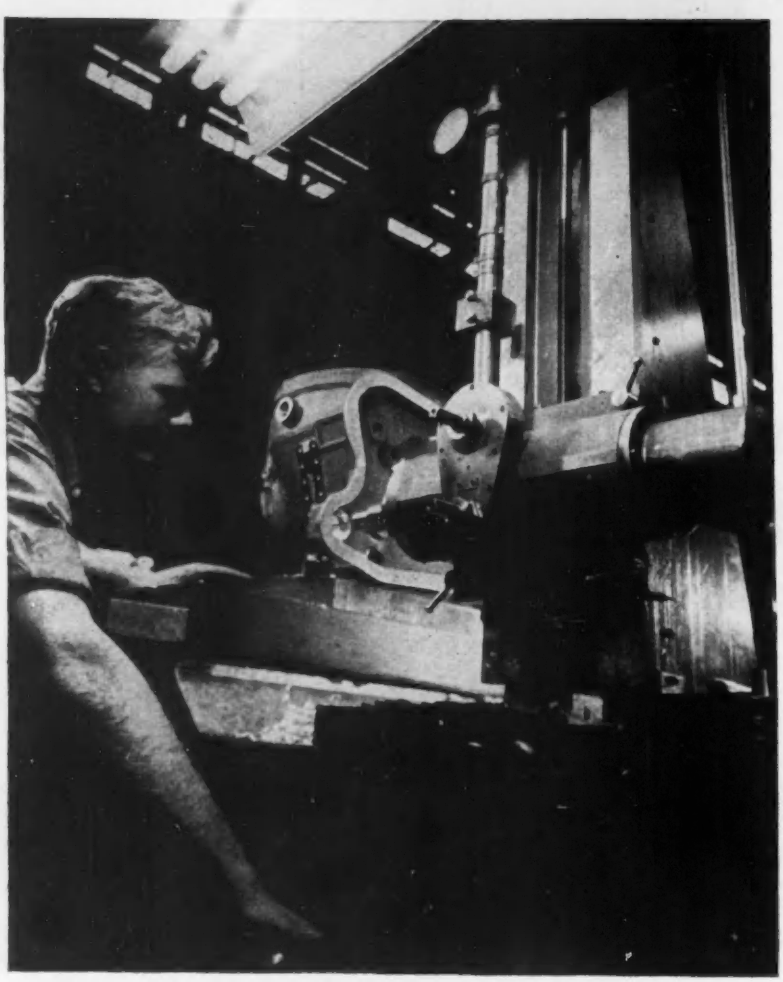

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NEW BOOKS

Electronics for Communications Engineers

JOHN MARKUS *and* VIN ZELUFF, *Associate Editors, Electronics Magazine, 610 pp, 8½ x 11 in. Published by McGraw-Hill Book Company, 330 West 42 St., New York 36, N. Y., $10.*

This book brings to engineers in easy-to-use form the important radio communication, radio broadcasting, television and radar design articles that have appeared in Electronics during the past five years. The book is a sequel to "Electronics for Engineers" and "Electronics Manual for Radio Engineers," which similarly made available in convenient reference form the same type of material from earlier issues of this magazine.

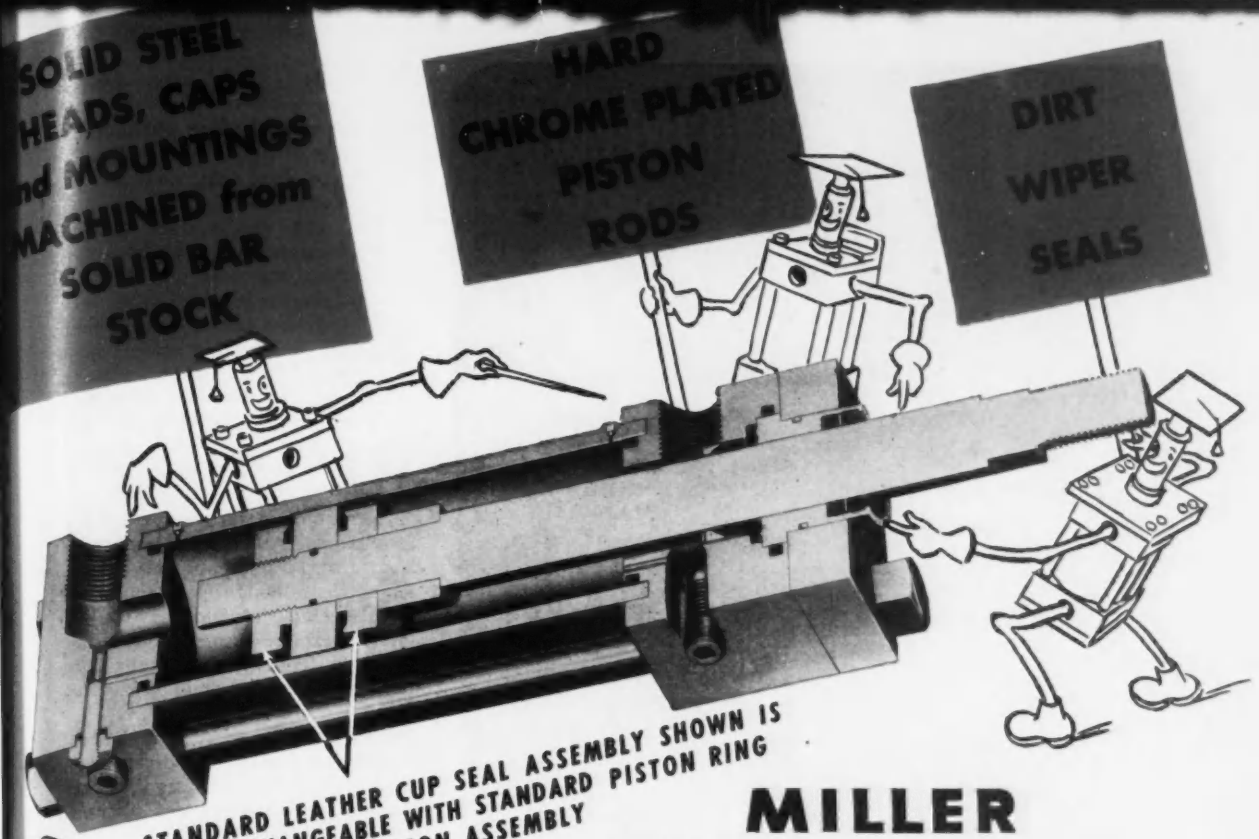
For this third book, the new material was carefully selected, checked, edited and condensed to have maximum reference value. The resulting 252 articles were then logically arranged by subject matter into fifteen chapters, so that each chapter constitutes a comprehensive survey of recent developments. Designers, builders and users of electronic equipment will find here the equations, charts, nomographs, tables and other reference data that are so hard to find in loose copies or bound volumes of the original magazine.

Chapters are arranged in alphabetical order so that oftentimes chapter headings alone serve to locate the desired information, as follows: Amplifiers; Antennas; Audio; Cathode-Ray Tubes; Components; Electronic Music; Filters; Measurements; Microwaves; Oscillators; Power Supplies; Propagation; Pulses; Receivers; Transmission Lines; Transmitters.

ASTM Standards on Copper And Copper Alloys

520 pp. Published by the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. $4.75.

This latest edition (February, 1952) brings together in convenient up-to-date form all of the ASTM standards pertaining to copper and copper-base alloy products. These standards were developed by Committee B-5 on Copper and Copper Alloys, Cast and Wrought, and other ASTM technical committees. It is the direct result of close cooperation of the technical rep-



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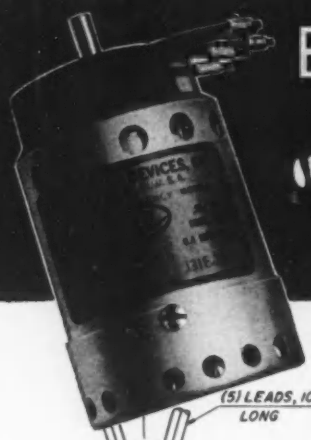

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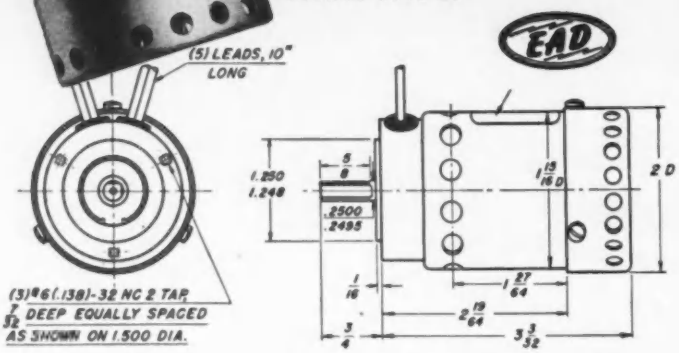

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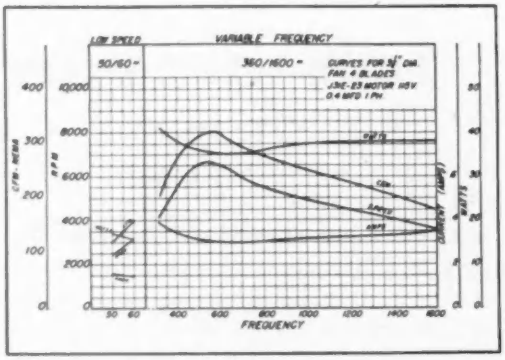

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resentatives of leading producers and consumers of copper and copper alloys serving on these committees and provides a wealth of data.

The 114 specifications and test methods contained in the book cover plate, sheet, rolled bar and strip; rod, bar and shapes; pipe and tubes; wire; sand and die castings; arc-welding electrodes and brazing solder; standard nominal diameters and cross-sectional areas of American Wire Gage (AWG) sizes of solid round wires used as electrical conductors; stranded conductors and other electrical usages of copper.

A group of specifications cover nonferrous metals such as slab zinc; pig lead; nickel; phosphor, silicon, and electrolytic cathode copper and others.

This volume contains test methods covering expansion, mercurous nitrate, resistivity, tension, micrographs, hardness, sampling, and grain size evaluations.

Also included are recommended practices for tension test specimens for copper-base alloys for sand castings and designating significant places in specified limiting values.

Technical Cooperation With Underdeveloped Countries

PHILIP C. NEWMAN, *Ph.D., Economist,* JOHN E. ULLMANN, *M.S., Industrial Engineer,* ROBERT S. ARIES, *D. Ch. E., Chemical Engineer,* 98 *pp,* 6 x 9 *in. Published by Chemonomics, Inc.,* 400 *Madison Ave., New York* 17, *N. Y.* $5.

Current interest of many American manufacturers is in the opportunities offered by economically underdeveloped countries. Aside from the Point 4 program, companies are seriously examining the development potential of countries in Latin America, Africa and Asia, which have the raw materials, but need capital and technical know-how. These are the challenging new frontiers for businessmen.

This book reviews and analyzes thoroughly what can be done in undeveloped areas in terms of concrete industrial planning. The subject is discussed both from a theoretical and a practical aspect. This reflects the combined efforts of the three authors: an economist, an industrial engineer, and a chemical businessman.

After defining the problem of technical assistance and the conditions and limiting factors in industrial growth, the book reviews methods of industrialization which have been used in the past, details and discusses the

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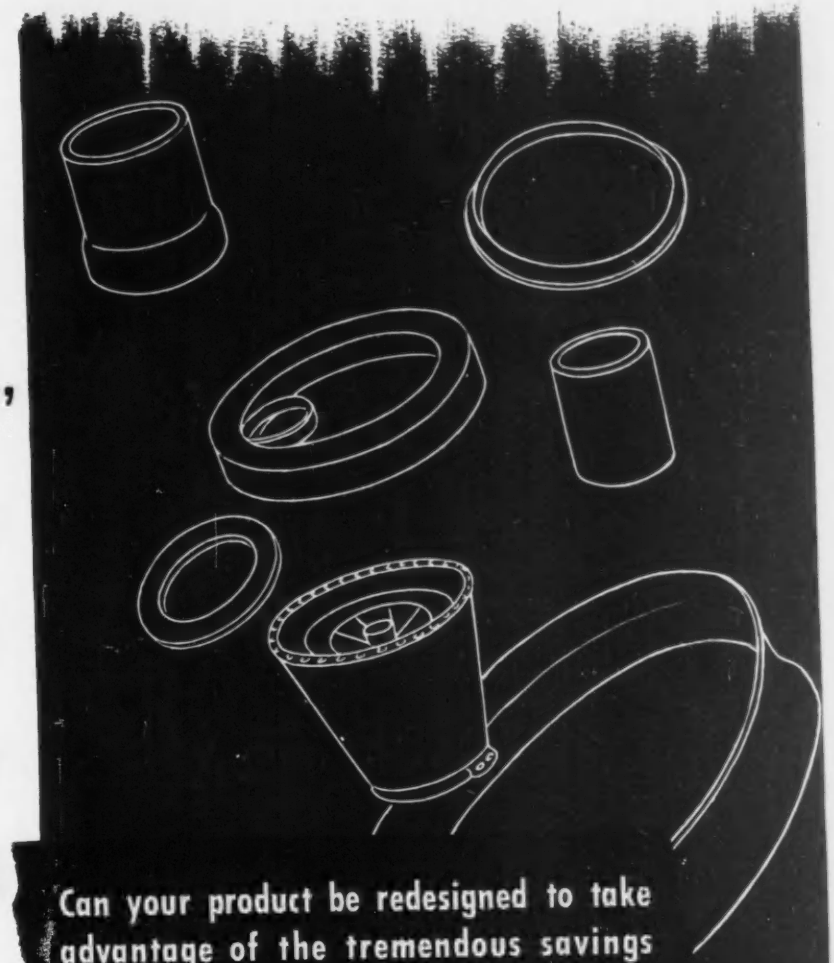

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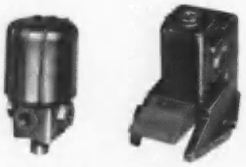
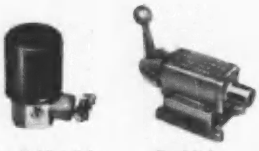
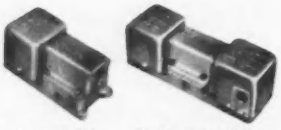


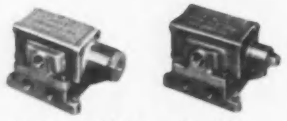
Solenoid In-Line Valve | Foot Valve



Solenoid Pilot Valve | Hand Valve



Solenoid Valve | Double Solenoid Valve



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basis of Point 4 industrialization and its potentials, and emphasizes the activities of local governments, national and international organizations. Four Latin American countries and the Colombo plan are examined as case histories in such development. Action by private investors, naturally, receives extensive treatment.

The value of this book is three-fold. It defines the problem of industrialization and sets up the criteria for such growth and analyzes past action in the light of these aims. Representative national and international development plans are examined in this respect. The book further discusses the need for reforms, organized assistance, and investment guarantees. The final phase of this work points out where and how private companies and technicians can participate in such developments. It is recommended reading for the business executive, investor, and technician.

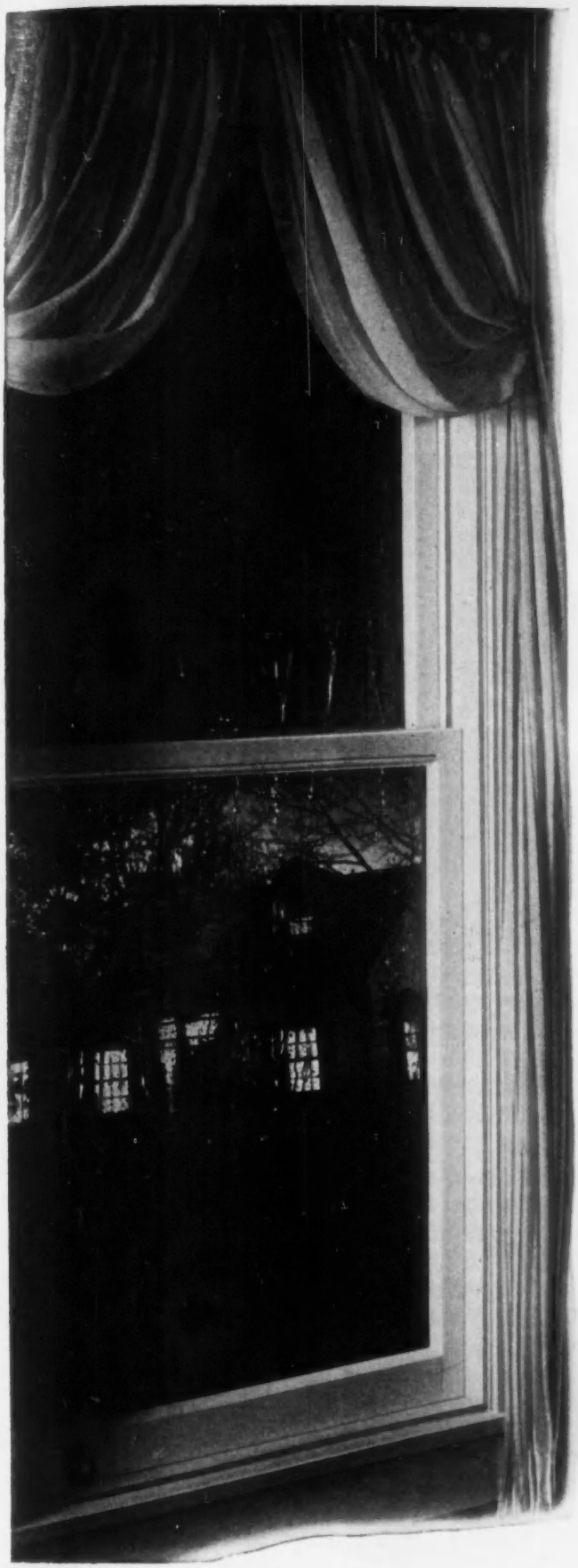
Elements of Physical Metallurgy

ALBERT G. GUY, *Associate Professor of Metallurgy, North Carolina State College, University of North Carolina. 293 pages, 7 x 9½ in. Published by Addison-Wesley Press, Inc., Cambridge 42, Massachusetts.* $6.50.

This is a textbook for courses in fundamentals of physical metallurgy. Since it treats basic principles, it is suitable for engineering and science students as well as for those whose major interest is metallurgy. An introductory section orients the student and briefly surveys the background that gives significance to the principles discussed in the body of the text.

The introductory section is followed by four chapters on the structure of metals and alloys. Chapter 3 opens with an elementary consideration of atomic structure, starting with the concepts of quantization of energy and continuing through the Bohr and wave theories of atomic structure. Nuclear structure and nuclear reactions of interest in metallurgy are also considered. The solid (crystalline) structures produced by an assembly of atoms are taken up in Chapter 4, along with a brief discussion of liquid and gaseous metals.

Chapter 5, on equilibrium diagrams, continues the treatment of metallic structure. It considers the equilibrium relations that can exist among several solid, liquid or gaseous phases of the types described in the previous chapter. Actual alloy systems are used as illustrative examples wherever possible



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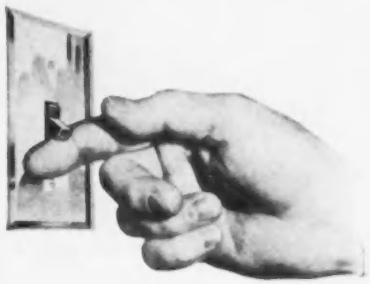

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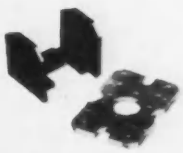

Insulator (left) made from Grade X Black Synthane for Square D Company and switch mounting plate made for Cutler-Hammer Inc. of Grade GLCC-M Synthane. Both parts require good electrical characteristics.

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Although the majority of timing problems can be effectively solved by devices considered "standard" in our line, we have had a great deal of experience in the design of special devices to meet specific requirements . . . and will welcome the opportunity to help solve your timing problem. Write us for complete information.
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—the magnesium one-component diagram, the copper-nickel and aluminum-silicon two-component diagrams.

A somewhat different aspect of phase structure is presented in Chapter 6, *Structure of Alloys*. Solid-solution formation, for example, is considered in terms of the Hume-Rothery rules. The relation of structure to the properties of alloys is illustrated by a study of steels, brasses and bronzes.

Chapters 7 to 10 further develop the concept that metallic structures and properties are related, but the emphasis is on properties of metals and alloys. This section begins with a chapter on physical properties—electrical and magnetic phenomena and the corresponding special alloys, thermal properties, and optical properties. Chapter 8 considers elasticity. The concepts of stress and strain are briefly reviewed, and the stress tensor and the strain tensor are discussed. Chapter 9, *Plasticity of Metals*, presents a quantitative theory of plastic deformation, including the ideas of flow stress, flow curve, and fracture stress. Chapter 10, *Corrosion*, emphases the mechanisms of corrosion and considers the types of corrosion control that are suggested by knowledge of these mechanisms.

The final section of the book, Chapters 11 to 14, treats the important topic of reactions in metals. Diffusion, which underlies almost 11 reactions in metals, is considered first and is illustrated by examples of oxide formation, carburizing, metal bonding and homogenization. Chapter 12 is devoted to quantitative aspects of recovery, recrystallization and grain growth. The subject of age hardening, including both precipitation hardening and order hardening, is considered in the next chapter. The transition lattice theory of hardening is described and illustrated by sketches. Chapter 14 covers the general problem of the heat treatment of steel.

Production Processes

ROGER W. BOLZ, *Assoc. Editor, Machine Design*, 357 *pp*, 6½ *x* 14¼ *in. Published by the Penton Publishing Company, Cleveland, Ohio.* $7.50.

Following the precepts of Volume I of Production Processes—Their Influence on Design, published in 1949, this accompanying book carries on to completion the coverage of major manufacturing methods. Here again the same uniform treatment of each method is pursued to permit a broad, fair analysis of all methods from the same design vantage point. A general

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The pipe manifold end is expanded to 2.225" I. D., a flange superimposed, and a flanged ferrule press-fitted for immediate assembly to exhaust manifold. Two bending operations with minimum reductions permit full flow of gas to hold back-pressure to a minimum. Muffler end diameter of tube is increased by expanding and a bead superimposed to form a "gas-tight" joint.

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but brief introduction to the process itself and equipment employed in manufacturing is followed by attention to design detailing which will insure simple and economical processing.

As in the previous volume, a portion of each chapter is devoted to the selection of the most suitable materials, their processing attributes and possible limitations. Discussed also are practical shop tolerances which can be held under average manunfacturing conditions as well as the usual maximum range which can be drawn upon when necessary.

To create a logical grouping compatible with those of Volume I, the chapters have been arranged under four headings—casting methods, molding methods, fabricating methods, and treating methods. These divisions complete, and bring to a total of fifty-four, the major methods of design importance employed in manufacture.

The two books attempt to assist in bringing about a better understanding of the real economic importance of design for manufacture, and also help directly in conserving valuable time, labor and raw materials.

Introduction to Electrical Engineering, Second Edition

ROBERT PAGE WARD, *Professor, Agricultural and Mechanical College of Texas,* 412 *pp,* 6 x 9 *in. Published by Prentice-Hall, Inc., 70 Fifth Ave., New York* 11, *N. Y.,* $7.65.

This book is written as a text for electrical engineering students of the sophomore level. The mathematics used in the text is, therefore, limited in the earlier chapters to algebra and trignometry, with the concepts of rate of change and derivative introduced later in the chapter on electromagnetic induction. Derivations using calculus have for the most part been placed in footnotes in order that the main text might be followed by those not familiar with calculus.

In this new edition, the discussion of certain topics has been amplified so a beginning student may gain a better understanding of them from reading the text. This makes the book of more value to men using it for home study or reference. An attempt has been made to clarify further the matter of voltage notation and to improve the manner of stating the definitions of electric and magnetic field intensity and flux density.

About 250 additional questions and problems have been included. The Study Questions at the end of each chapter are designed to stimulate in-

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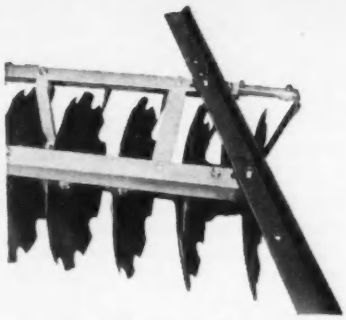

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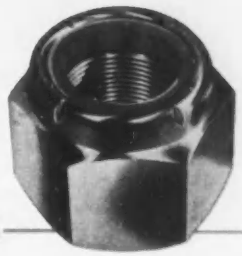

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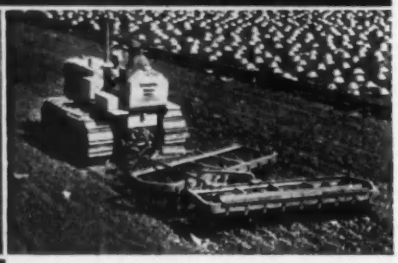

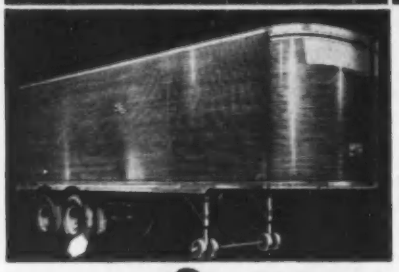

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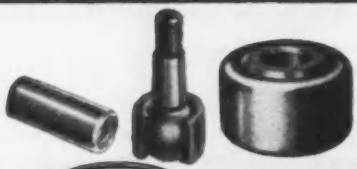

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dependent thought about the principles discussed and their applications. Obvious questions such as "What is the MKS unit of force?" and "In what way does the resistance of a metal conductor vary with temperature?" have generally been avoided. Most of the factual data needed are contained in the text, but it is not intended that the answers to the questions can be read verbatim from the book. Some of the questions are, in fact, problems and appreciable time is required for their solution.

Chemical Engineering Techniques

B. E. LAUER *and* R. F. HECKMAN, *University of Colorado.* 496 *pp,* 6 x 9 *in. Published by Reinhold Publishing Corp.,* 330 *W. 42nd Street, New York* 36, *N. Y.* $6.

Emphasizing technique rather than specific equipment, this volume provides an unusually complete and thoroughly rational assemblage of industrially proven methods for conducting chemical manufacturing operations. Its primary purpose is to acquaint the general reader with the many important considerations involved in the selection of the most suitable method for performing any of the several manufacturing tasks carried on in the chemical and process industries.

Throughout the book, equipment is shown in its true position—that of a tool rather than a method. The reader is continuously shown that, although technique and equipment are sometimes inseparable, technique is fundamentally the more important consideration.

Although directed primarily to chemical engineering students, this book will prove of value to any other student expecting to be employed in a chemical or process industry. It is also suited to all professional engineers and chemists, and to executives in many fields who need a simple, clearly-defined book as a practical means of understanding the field and interest of the chemical engineer.

Extrusion of Plastics, Rubber and Metals

HERBERT R. SIMONDS, ARCHIE J. WEITH *and* WILLIAM SCHACK. 454 *pp,* 6 x 9 *in. Published by Reinhold Publishing Corp.,* 330 *W. 42nd St., New York* 36, *N. Y.* $10.

The first part of the book, comprising about two-thirds of the material, is devoted exclusively to the extrusion of

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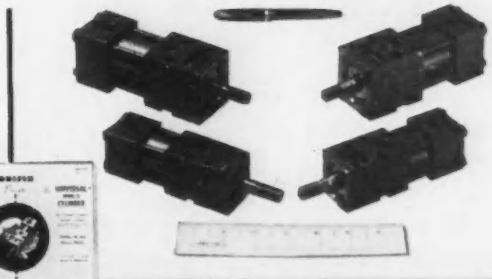

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plastics. Here, the versatility of the extruding machine as an industrial unit is fully described and the many applications of extruded plastics are discussed. All commercially important methods of dry extrusion such as multiple-screw machines, multi-colored products, sheets and films, and methods of compressing, pelletizing and extrusion packaging are described in a detailed yet easily understandable manner. The remainder of the book focuses attention on extrusion of metals, i.e. sheet, rods, billet, and such material as rubber, food products, ceramics, graphite, and even ice. With special attention given to recent advances in the field, the book offers a combination of the technical and practical approach, all descriptions of extrusion methods being carefully geared to the nature and actual operation of factory equipment.

All branches of the industry—die design, equipment engineering, process control, materials used, cost computation—are covered in a manner comprehensible to the novice in the field and of technical assistance to those actively engaged in it, such as molders, fabricators of plastic materials, processors of food products, waxes and similar materials and development engineers.

Electric Machinery

A. E. FITZGERALD *and* CHARLES KINGSLEY, JR., *both Associate Professors, Massachusetts Institute of Technology,* 702 *pp,* 6 x 9 *in. Published by McGraw-Hill Book Co., Inc.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $8.50.

Intended for undergraduate machinery courses in electrical engineering, this text presents the theory in a manner which highlights the basic principles common to all rotating electric machines, as well as a wide variety of electromechanical-energy-conversion devices. This basic theory is then applied to d-c synchronous, polyphase induction, and single-phase machines, together with Amplidynes, Rototrols, and Selsyns. Transformers are included because of the many similarities in thought processes involved in their study. The treatment ends with introductions to machine transients and to the dynamics of electromechanical systems.

A unified, integrated treatment of the various machine types is presented. D-c machines and the various types of a-c machines are all seen to be based on a common set of principles for the production of torque and volt-

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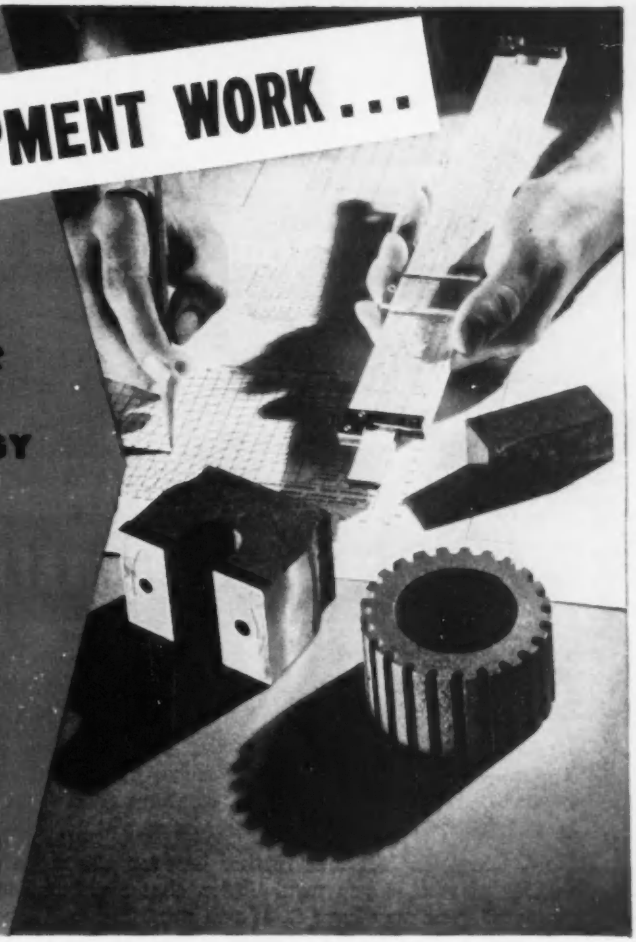

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age. These principles are in turn correlated with those underlying the general problem of electromechanical energy conversion.

The questions of how machines work and, in particular, how torque is produced are thoroughly examined; and detailed theories and performance features unfold naturally as logical consequences of a few basic principles.

Specific applications of principles and methods of analysis are illustrated by a variety of examples, with complete solutions distributed throughout the book.

Resumés are given at the ends of chapters, which summarize and show the engineering significance of what has been accomplished.

Design Manual for the Repair of Aluminum Alloy Structures

Edited by HOWARD M. JENSEN. 208 *pp*, 6 x 9 *in. Published by The Johnson Research Corp., Bethpage, L. I., N. Y.* $3.50.

This manual was compiled to fit the need for a guide furnishing vital data for the designer and mechanic on maintenance repair of aluminum alloy structures.

While the subjects herein are applicable to almost any field in which light aluminum alloy structure is used, the airplane was selected as representative of the greatest number and most diversified examples of their use. The information and methods suggested are the latest and most accurate, consistent with current experience and practice. All the data have been checked for technical accuracy by experienced aircraft construction and repair men, by aeronautical stress analysts, design engineers and aircraft builders. The material has been organized to avoid conflict with AN designed parts, descriptions, and procedures.

Section I contains general information on types of damage and reviews the accepted methods for their detection and analysis. The emphasis is on the practical rather than theoretical approach.

Section II describes and evaluates various materials and processing methods. Comprehensive data is included on problems in repair that are important in structural aluminum, such as handling of extrusions, the principal fasteners, rivets, screws, bolts, welding, etc., air and pressure tightness, finishing methods and mass balancing of aircraft control surfaces. In-

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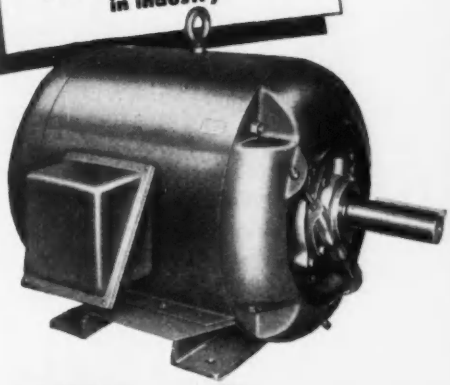

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cluded, is considerable data on steel tubing and its repair.

Section III treats the actual repair problems and typical examples. Problems are illustrated in detail with perspective drawings and tables. Problems of dissimilar metals in contact will be found particularly useful for structures involving aluminum and other metals.

Section IV is a description of standard fasteners with specifications, sizes, weights, materials, AN numbers, etc.

Section V is an appendix of useful information in the form of mathematical tables, solutions of various formulas, equations, etc.

Farm Gas Engines And Tractors

FRED R. JONES, *Professor and Head of Agricultural Engineering Department, Agricultural and Mechanical College of Texas,* 490 *pp,* 6 x 9 *in. Published by the McGraw-Hill Book Co.,* 330 *West* 42 *St., New York* 36, *N. Y.,* $6.

In this third edition, a large part of former subject matter has been completely revised to bring it fully up to date. Some changes have been made in chapter sequence, and a chapter on basic thermodynamics and its application to heat-engine design has been added to adapt the book to the growing need for a more technical treatment of powerplants for farm applications and tractor design principles. New developments that apply to automotive and stationary farm machinery such as the use of liquefied-petroleum gas as a tractor fuel, hydraulic transmissions, and hydraulic controls are now included.

The text deals with the construction, design, and operation of the internal-combustion engine as a stationary farm power unit and the tractor as an automotive farm power unit.

Topics discussed include engine construction and design, tractor-engine types and construction, valves and valve operation, fuel-supply and carburetion systems, air cleaners, cooling systems, governing and governing systems, ignition methods, storage cells and batteries, electric generators, lubricants and lubrication systems, tractor clutches and tractor transmissions and accessories.

In the appendix are presented the ASAE-SAE Standards: Tractor Testing Code; Power Take-Off and Drawbar Hitch Locations; and Application of Hydraulic Remote Control to Farm Tractors and Trailing-Type Farm Implements.

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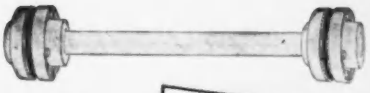

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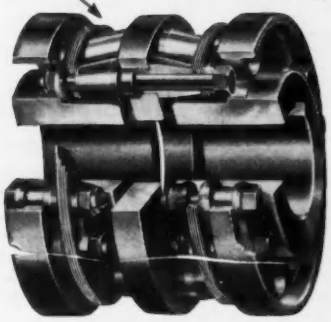

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